SIRS Model

Overview

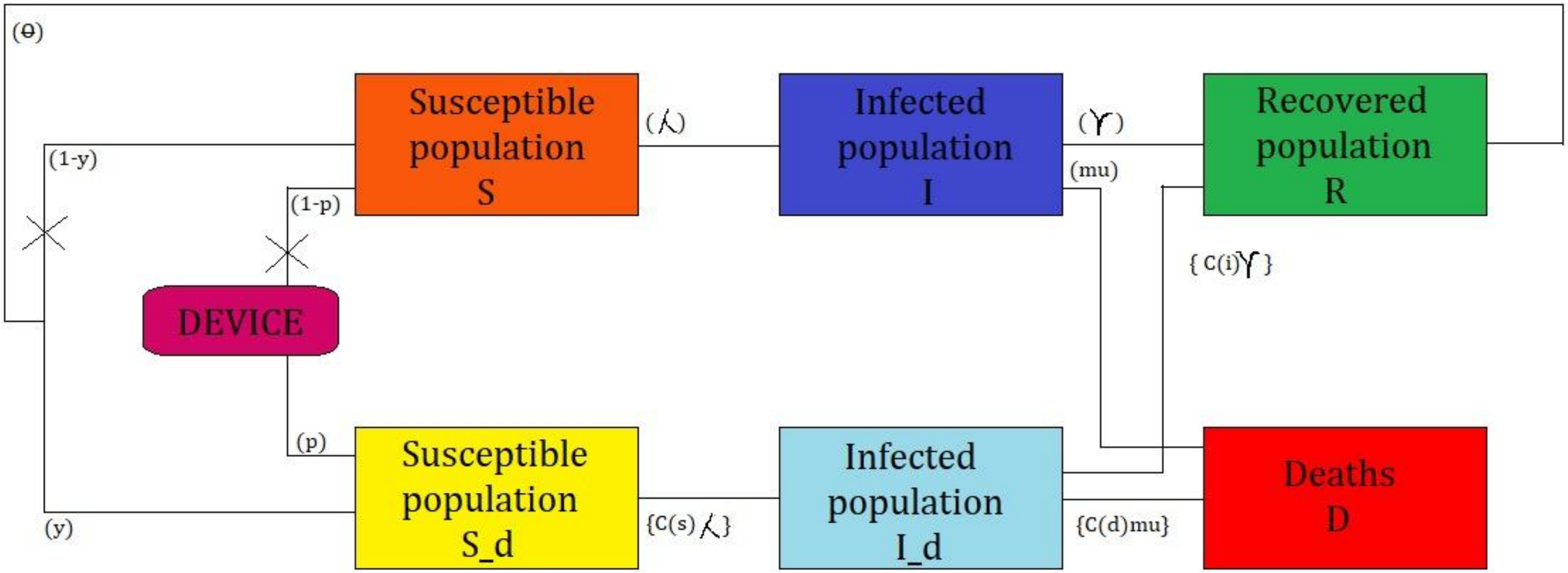
- Objectives
- Model , its description and Parameters
- Differential Equations
- The Code
- Various Graphs Compairing outputs with device and without device
- Insights and Inferences
- References

Objectives

- Obtain a better understanding of the Current Situation and in nearby future.
- Test hypotheses about the system for feasibility.
- Study the change of nature of various graphs by altering the model’s parameters.
- Identify the "driving" variables - ones that performance measures are most sensitive to - and the inter-relationships among them.

Model

N = S + S_d + I + I_d + R - M



Model Parameters

λ(= force of Infection) = β *(Infected people at any instant)/(Total Population)

β = Transmission rate or Effective Contact rate

γ = Recovery rate

μ = Mortality rate

θ = wanning Immunity rate

p = fraction of People using device before infection

y = fraction of People using device after they get recovered from Infection

Note: c_s, c_i, c_d are factors by which there is reduction in Transmission rate, increase in recovery rate and reduction in Mortality rate respectively.

Assumptions

1. Constant (closed) population size, N

2. No demography (i.e., births and deaths)

3. Homogenous Population / well Mixed Population

Values of Parameters

$\beta = 0.09$ #Transmission rate

$c_s = 0.2$ #reduction in transmission rate

$\gamma = 0.047$ #Recovery rate

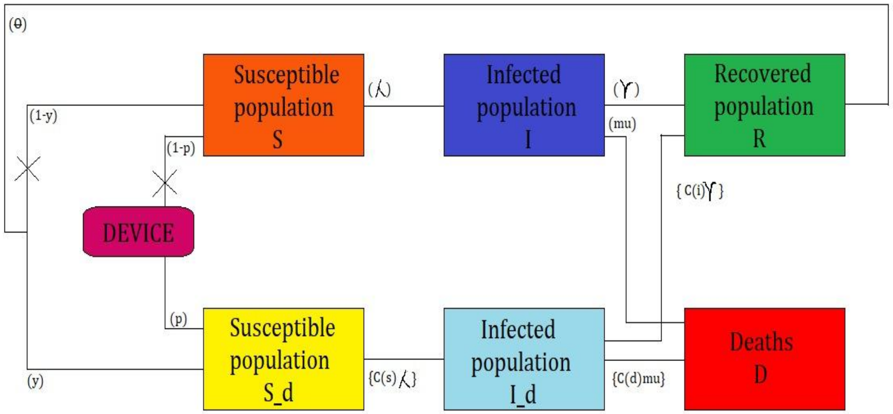
$c_i = 1.3$ #increase in recovery rate

$\mu = 0.0024$ #Mortality rate

$c_d = 0.8$ #decrease in mortality rate

$\theta = 0.00001$ # recovered to suspected rate

Differential Equations



dS/dt = -(1-p)*λ*S + (1-y)*θ*R

dI/dt = (1- p)*λ *S - γ*I - μ *I

d(S_d)/dt = -p*(c_s)* λ *(S_d) + y* θ*R

d(I_d)/dt = p*(c_s)* λ *(S_d) -(c_i)*γ*(I_d) - (c_d)* μ *(I_d)

dR/dt = γ*I + (c_i)*γ*(I_d) - θ *R

dDdt = μ *I + (c_d)* μ * (I_d)

Basic Reproduction Number : R naught(R0)

R0 $\propto$ (infection / contact) * (contact / time) * (time / infection)

More Specifically: R0 = $\tau * \bar{c} * d$

Where τ is the transmissibility (i.e., probability of infection given contact between a susceptible and infected individual),

$\bar{c}$ is the average rate of contact between susceptible and infected individuals,

d is the duration of infectiousness.

R0 Continued…...

Since, $\beta = \tau * \bar{c}$ and $\gamma = 1/d$

R0 is also defined as :

$$R0 = \beta/\gamma$$

In the Current Model,

$Ro = (1-p)* (\beta/(\gamma+ \mu)) + p*(\beta*c\_s/(\gamma*c\_i + \mu*c\_d))$

Effective Reproduction Number (Re)

- Re is the number of people in a population who can be infected by an individual at any specific time.
- For Simple Model: Re = R0 *S/N

$$Re = (1-p)^* (\beta/(\gamma+ \mu))(S/N) + p^*(\beta^* c\_s/(\gamma^* c\_i + \mu^* c\_d))(S\_d/N)$$

- It changes as the population becomes increasingly immunized
- It is affected by the number of people with the infection and the number of susceptibles with whom infected people are in contact
- People's Behaviour also affect its value.
- If Re>1, the infection will spread exponentially,
- If Re is less than 1, the infection will spread only slowly, and it will eventually die out.

USING DEVICE

Initial Values are considered as of the values on 20th June'2020 .

N = 10000000 # Total Population

I = 168658,   #Infected no. of people not using device

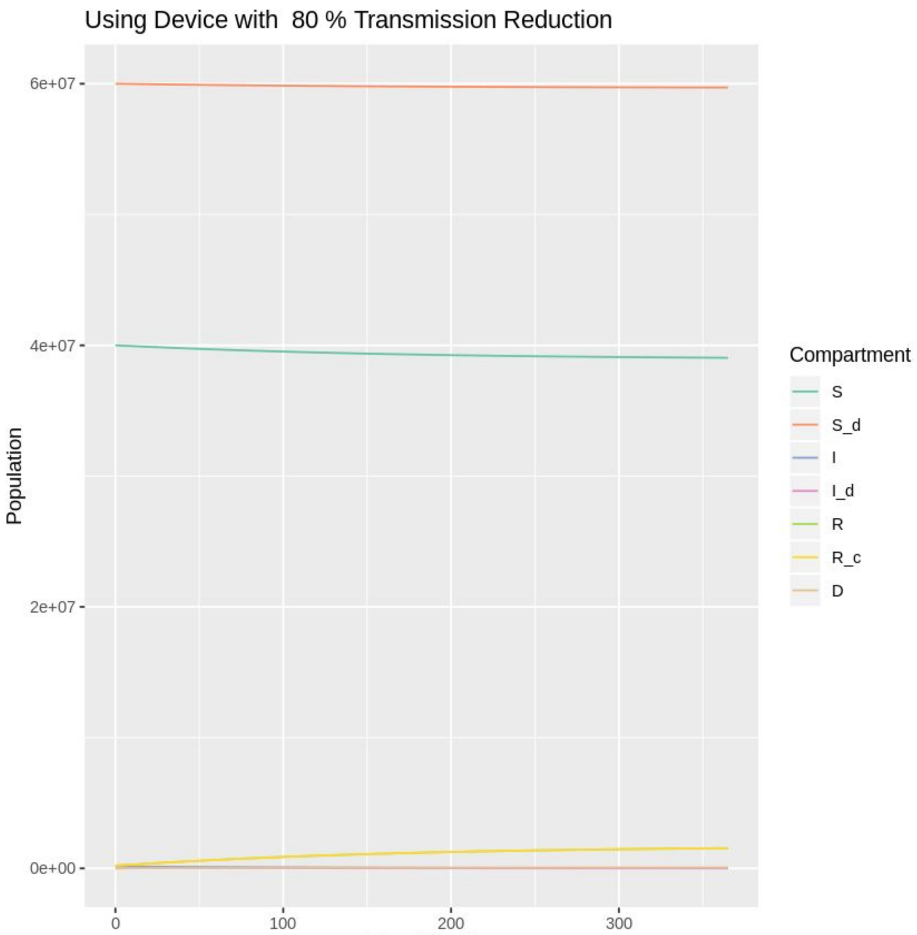
I_d = 3,   #Infected no. of people using device

R = 214210,   #Recovered no. of people

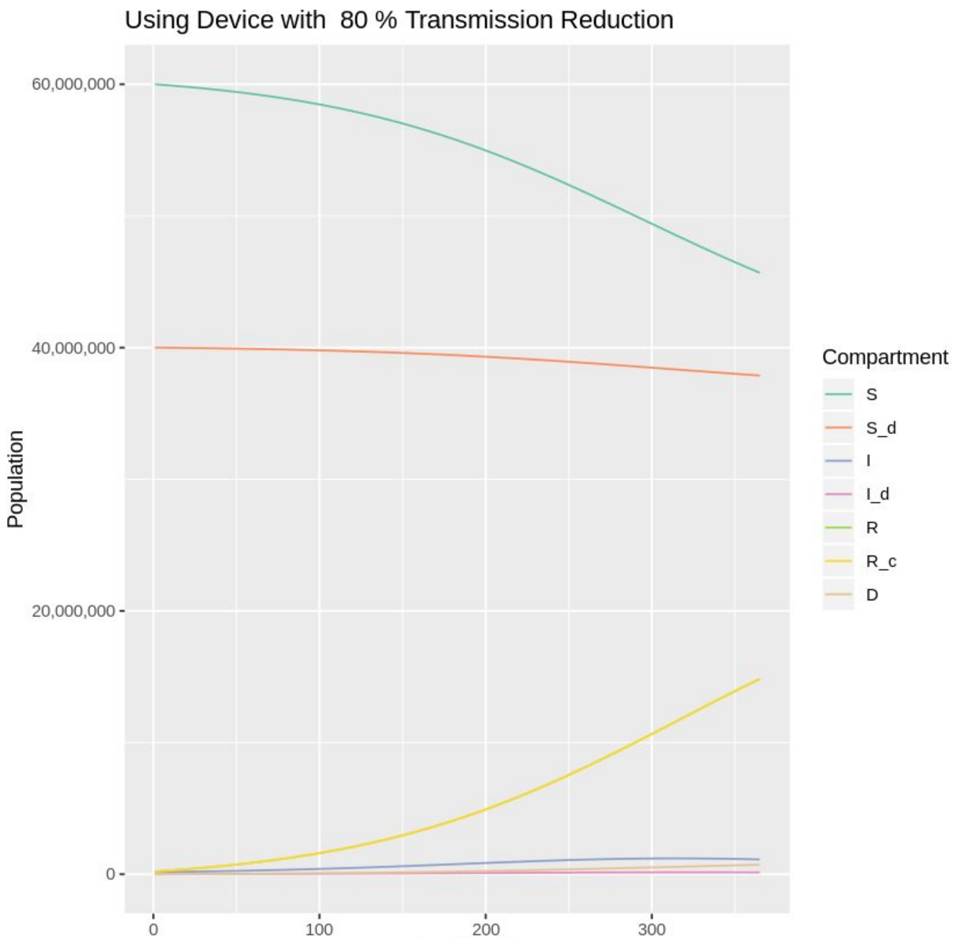
D= 12970   # Deaths

Plot of each compartment

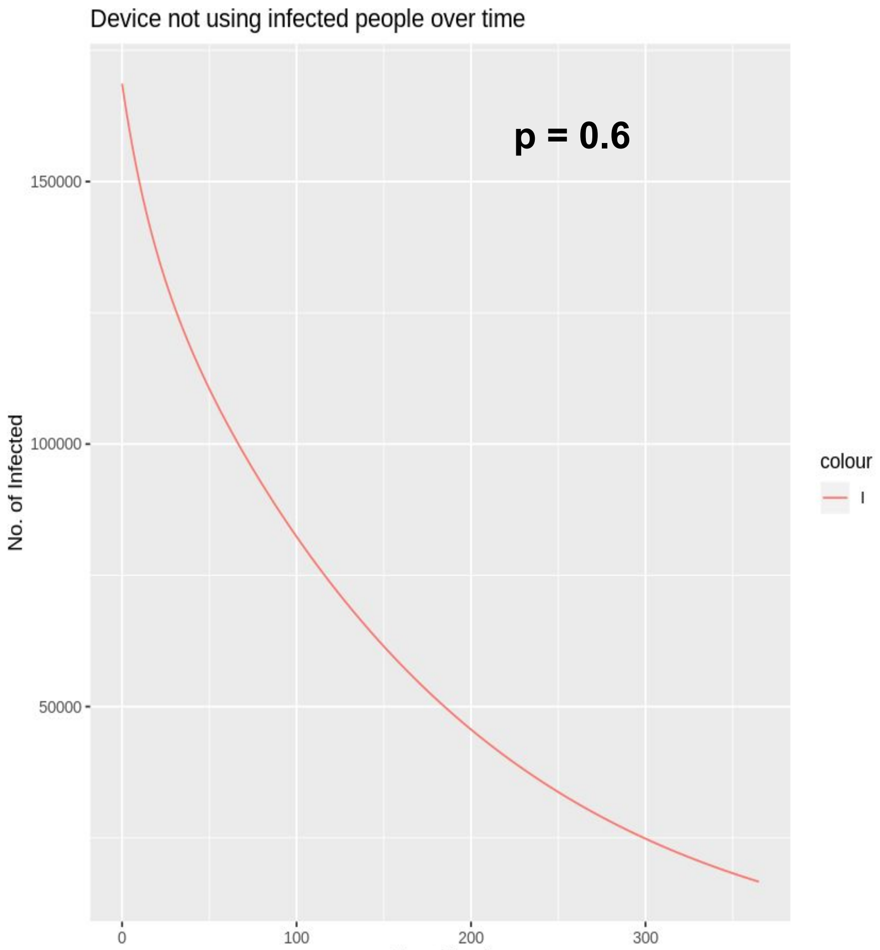
p = 0.6

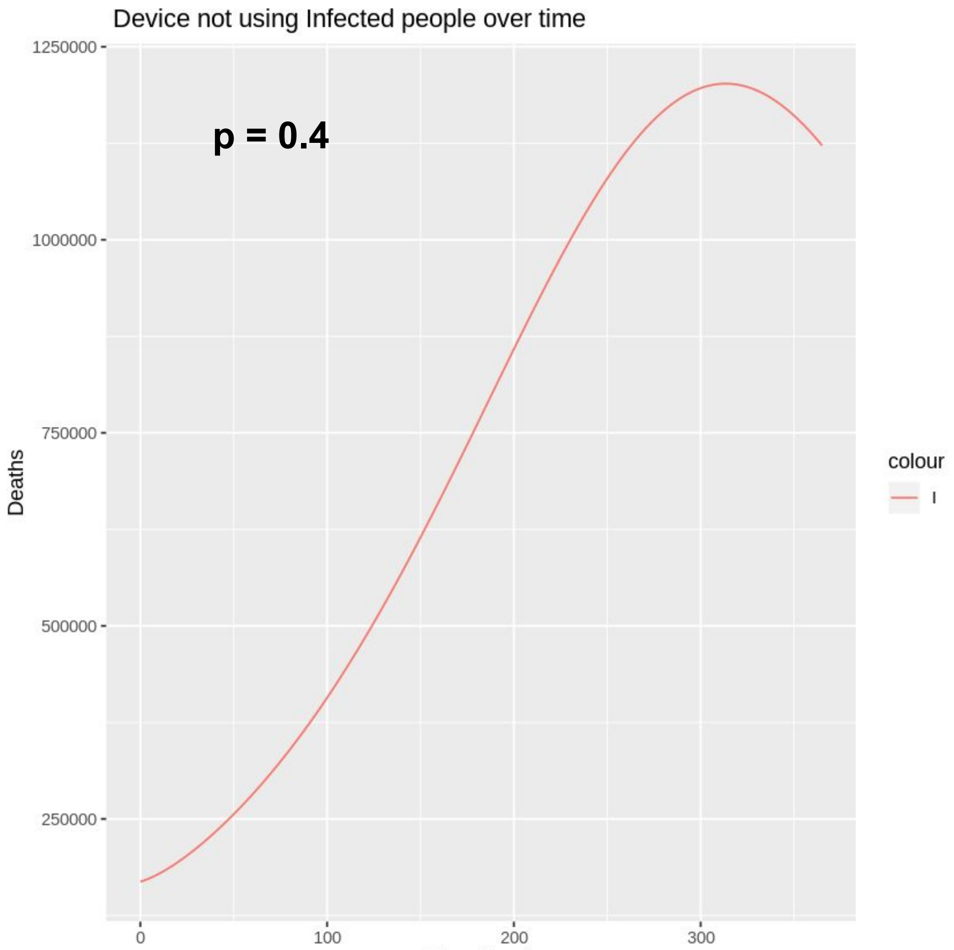


p = 0.4

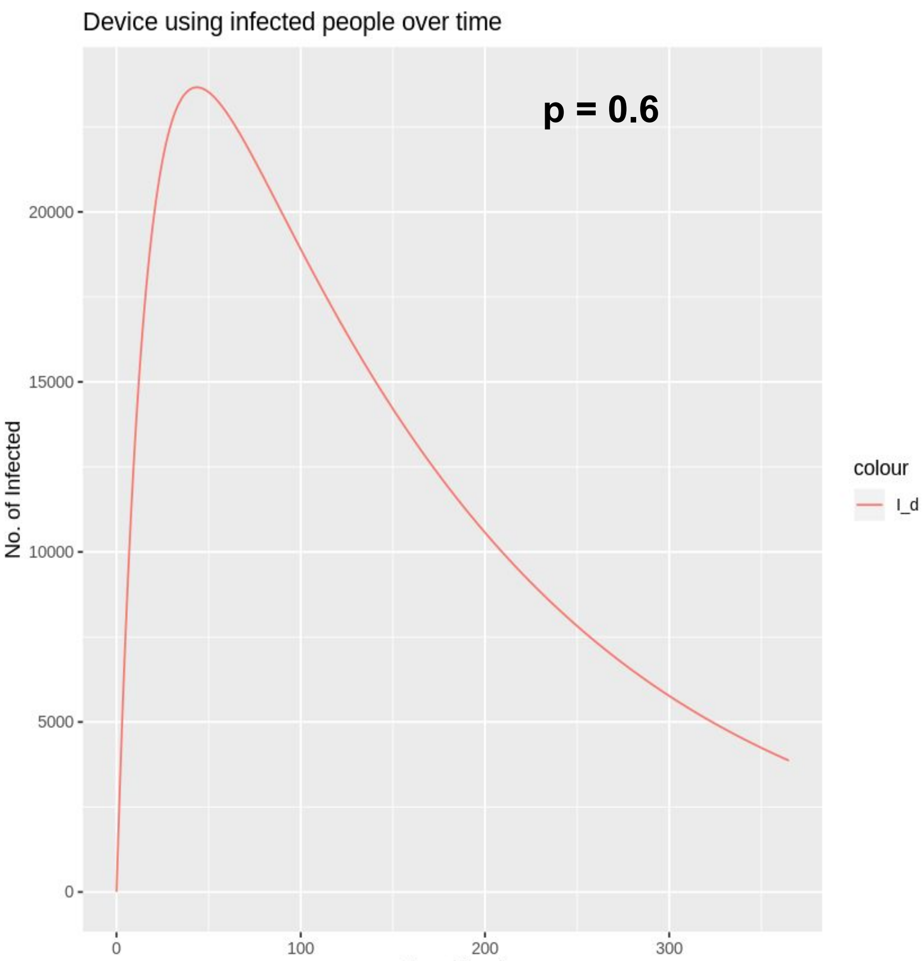


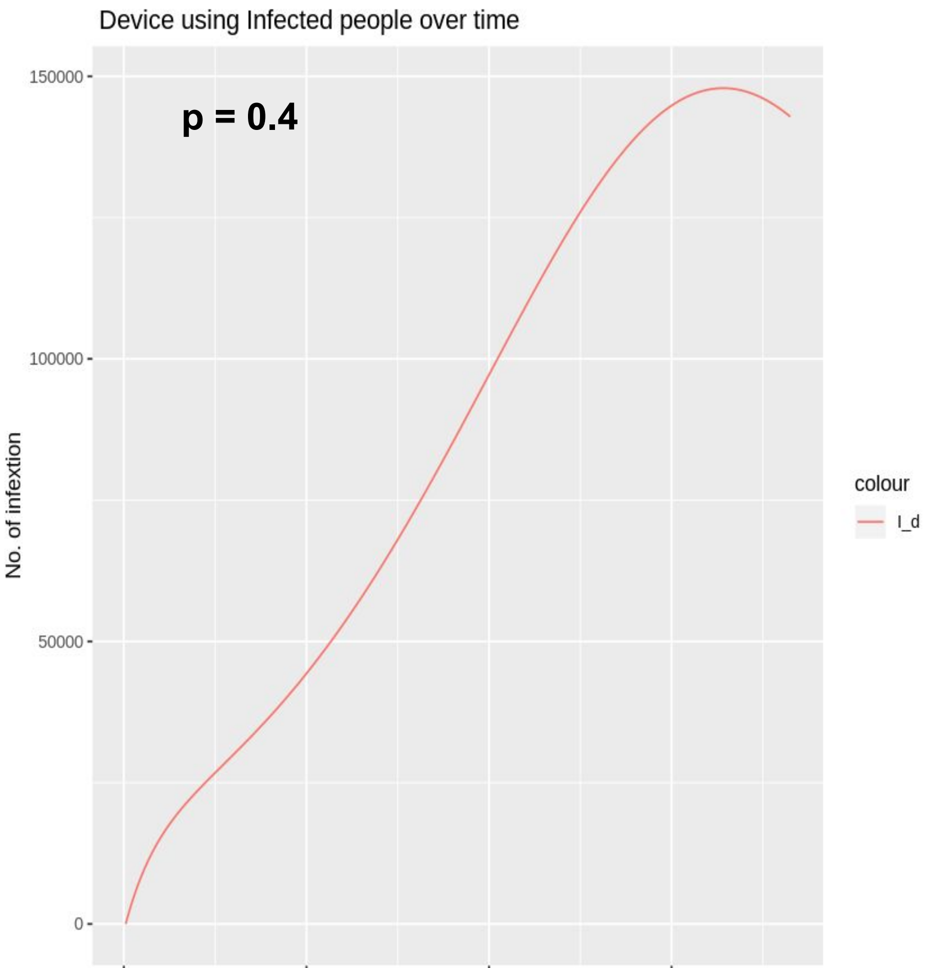
Total Active Cases in Device not using Compartment



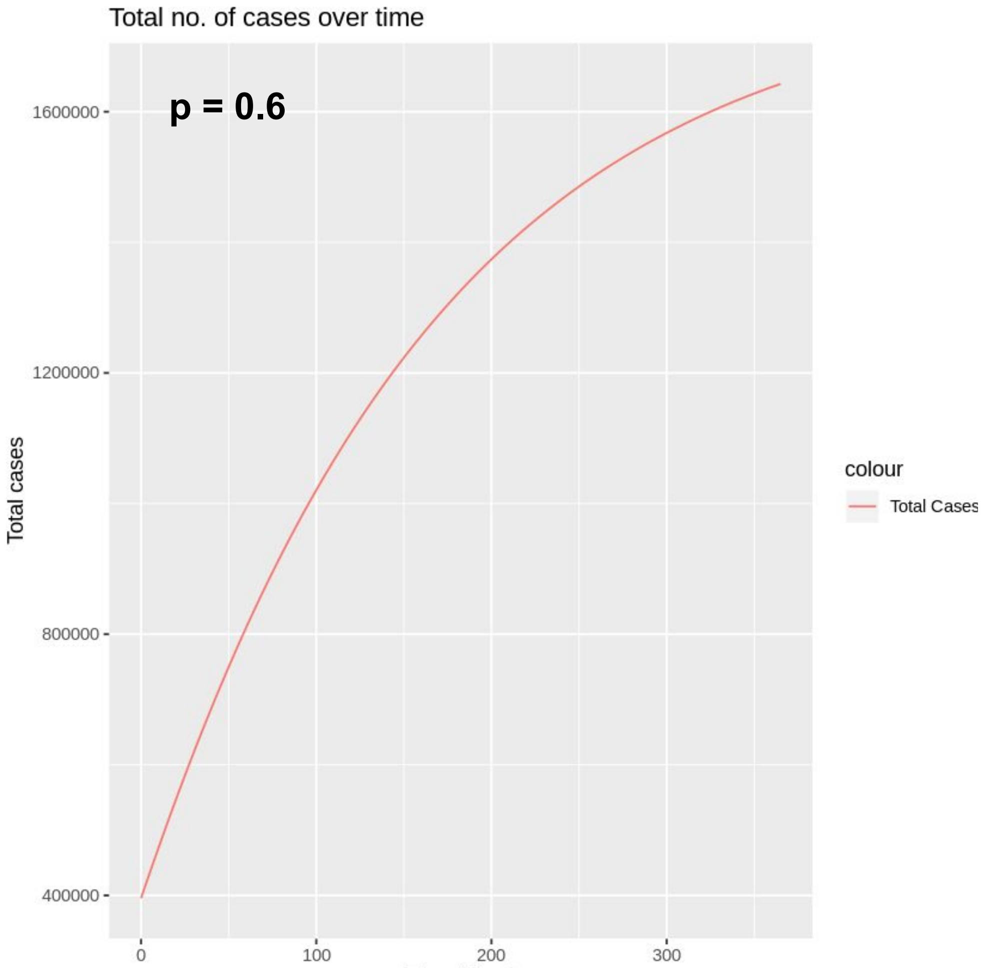


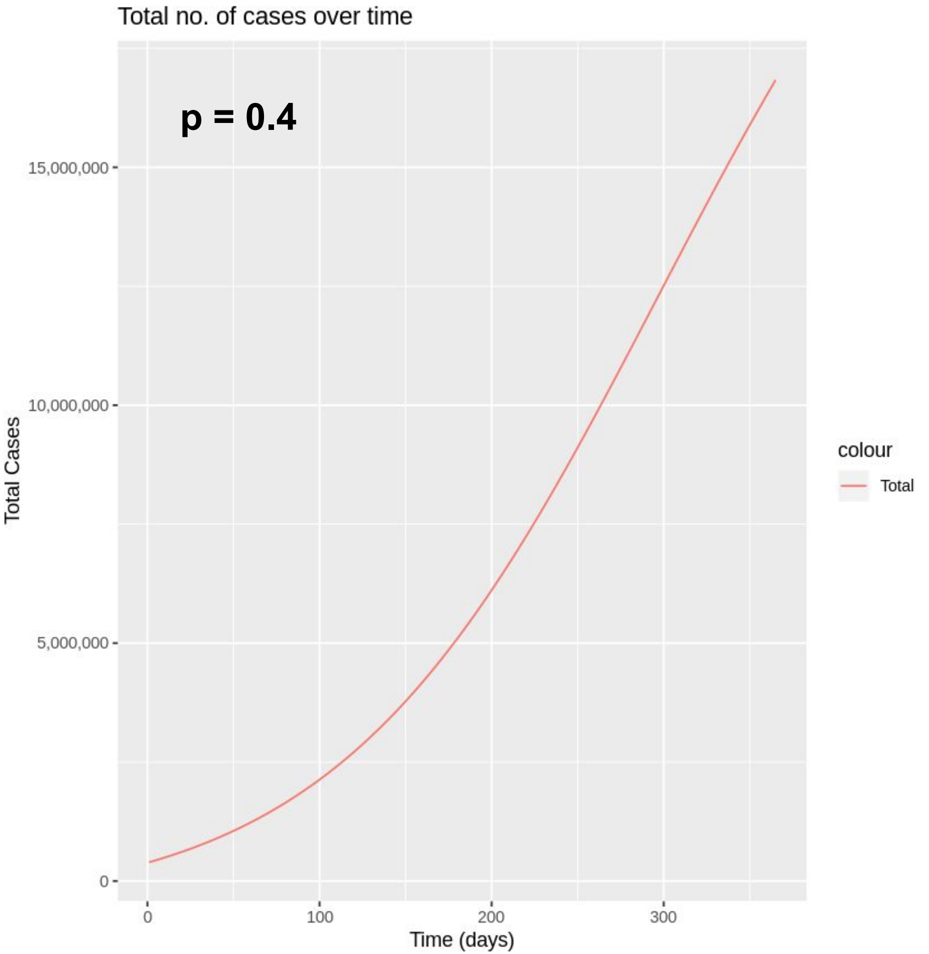
Total Active Cases in Device not using Compartment



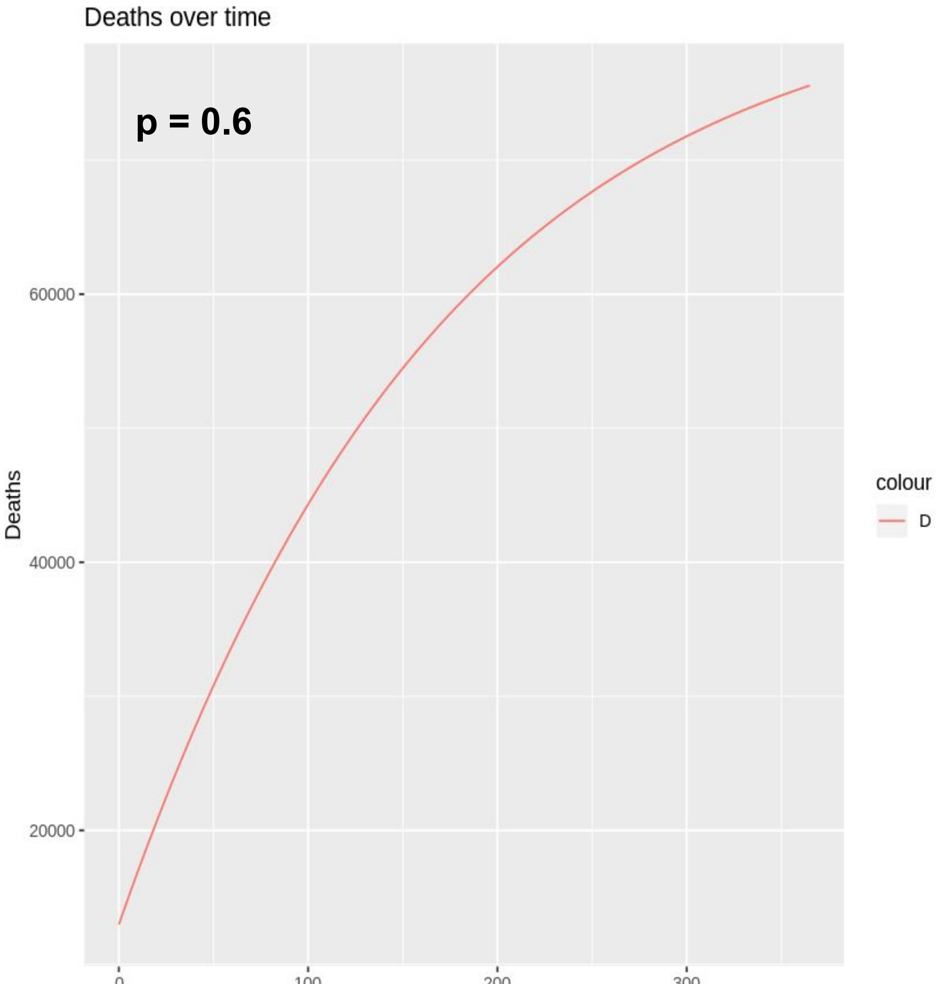


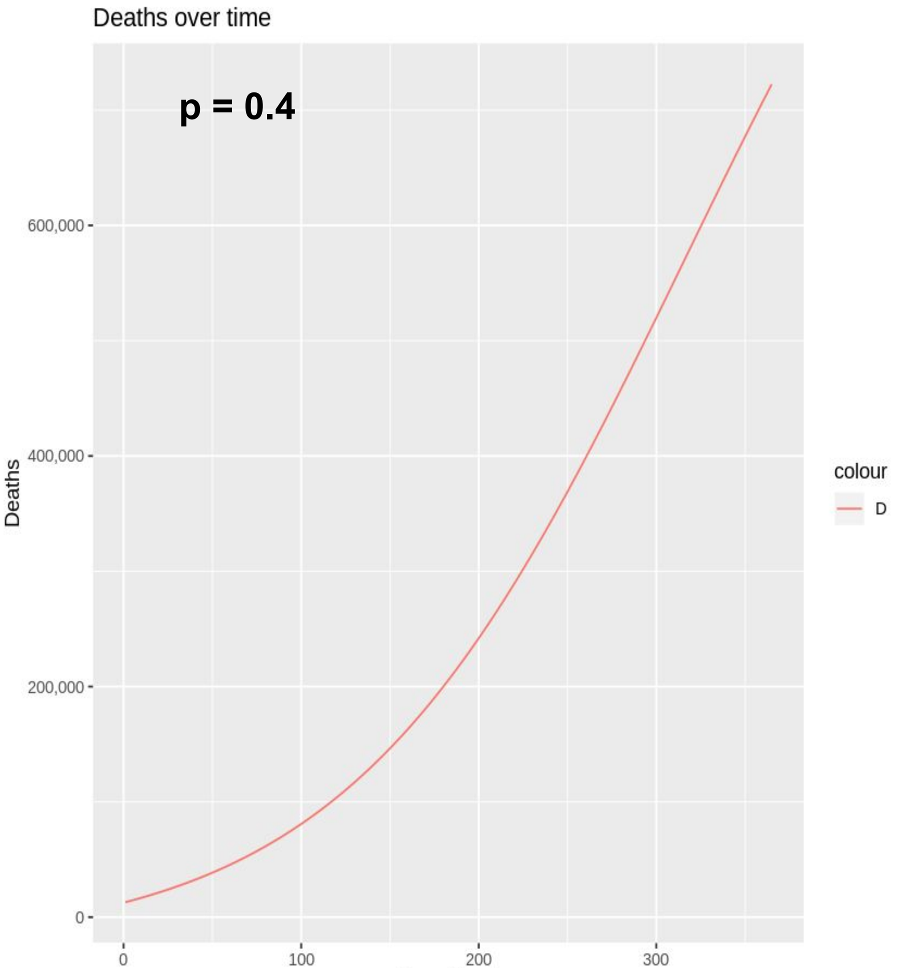
Total Infected Cases



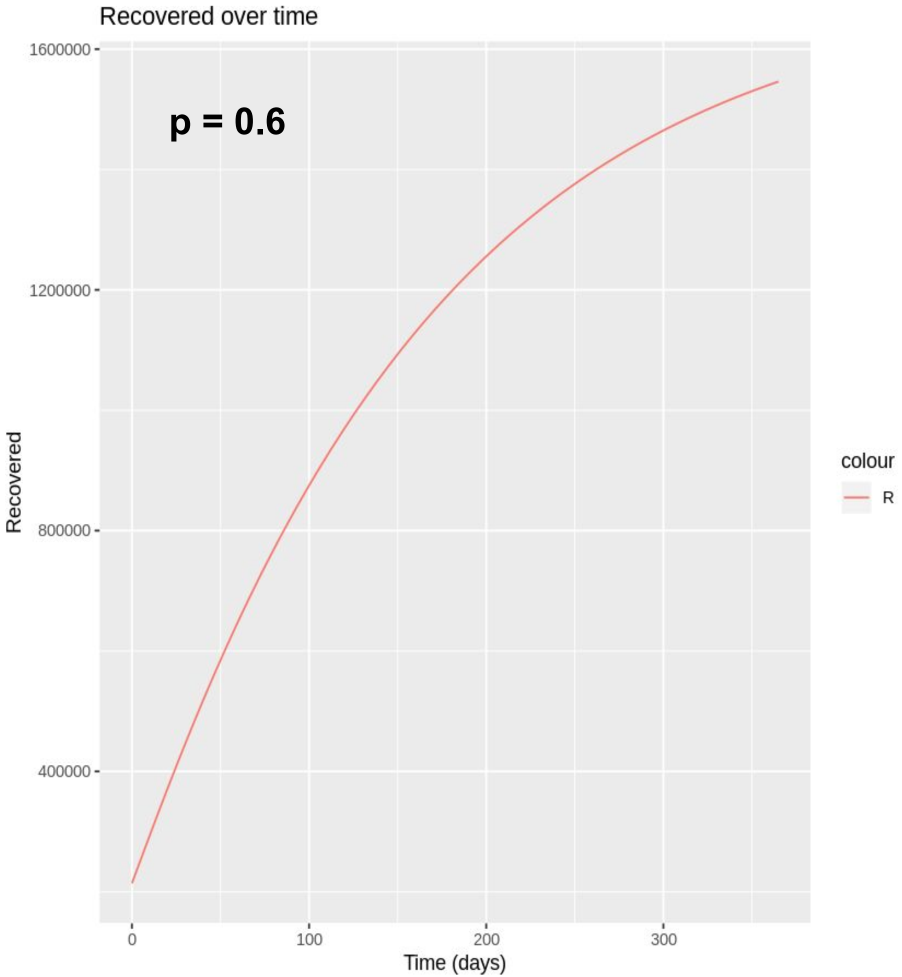


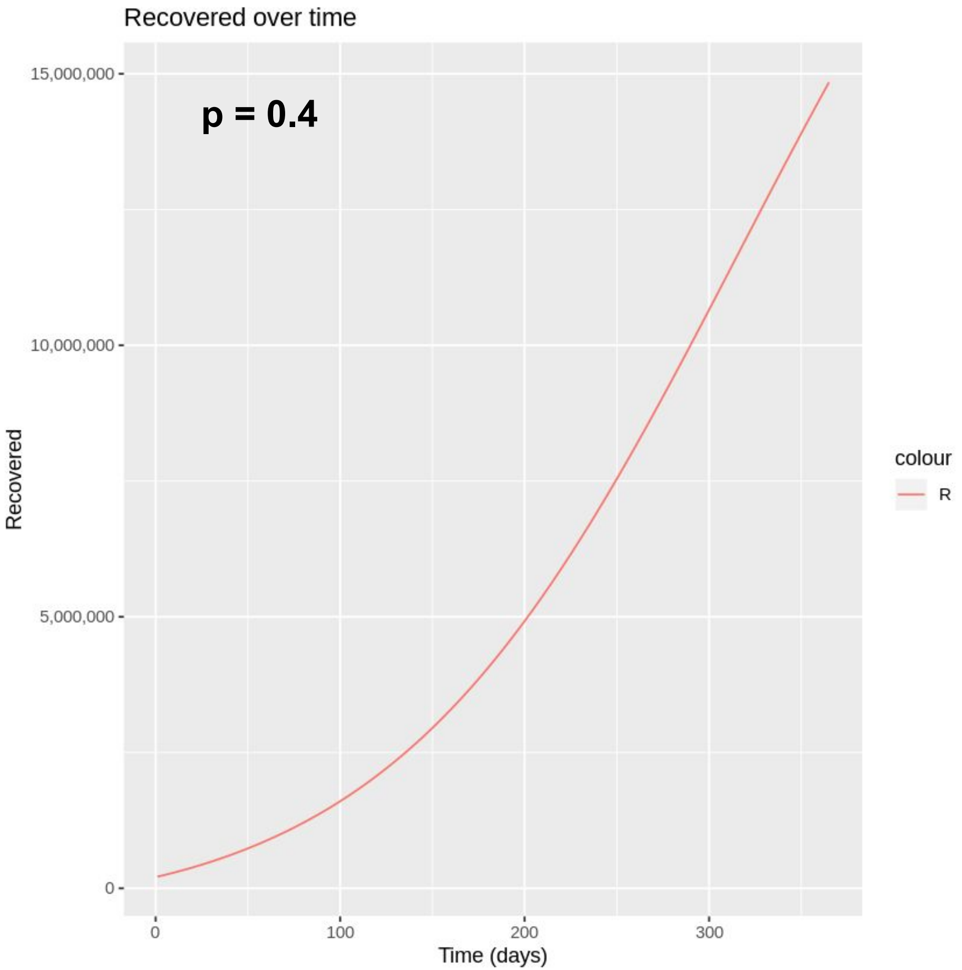
Total no. of Deaths over time





Total no. of Recovered over time





Max. value in each compartment

p = 0.6

I - 1,68,658

I_d - 23,661.91

D- 75,557.82

R- 15,46,533.55

Total - 16,41,641.97

p = 0.4

I - 12,02,126.57

I_d -1,47,897.13

D -7,25,368.90

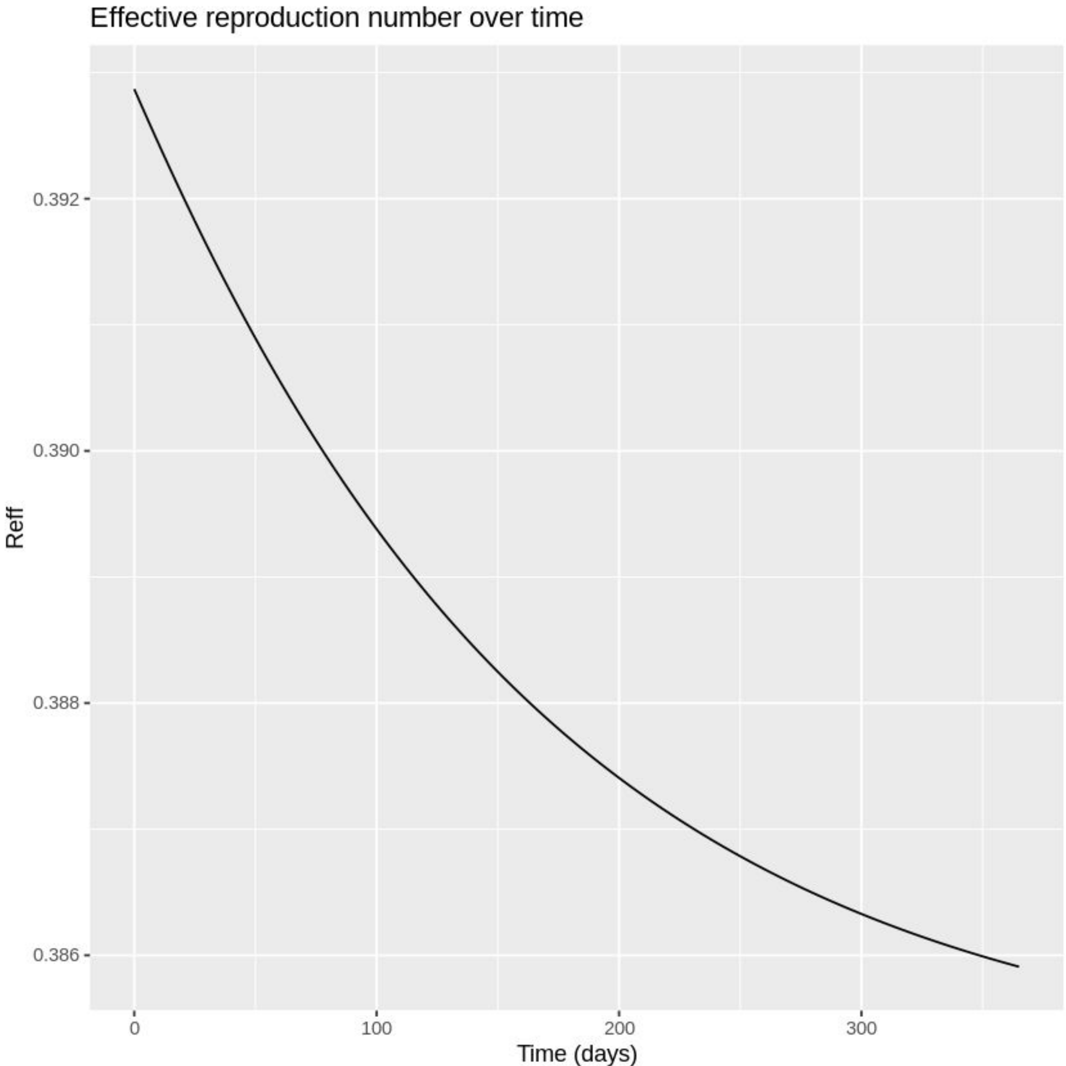
R - 1,49,06,955.10

Total - 1,68,35,687.34

p = 0.6

Ro and Reff

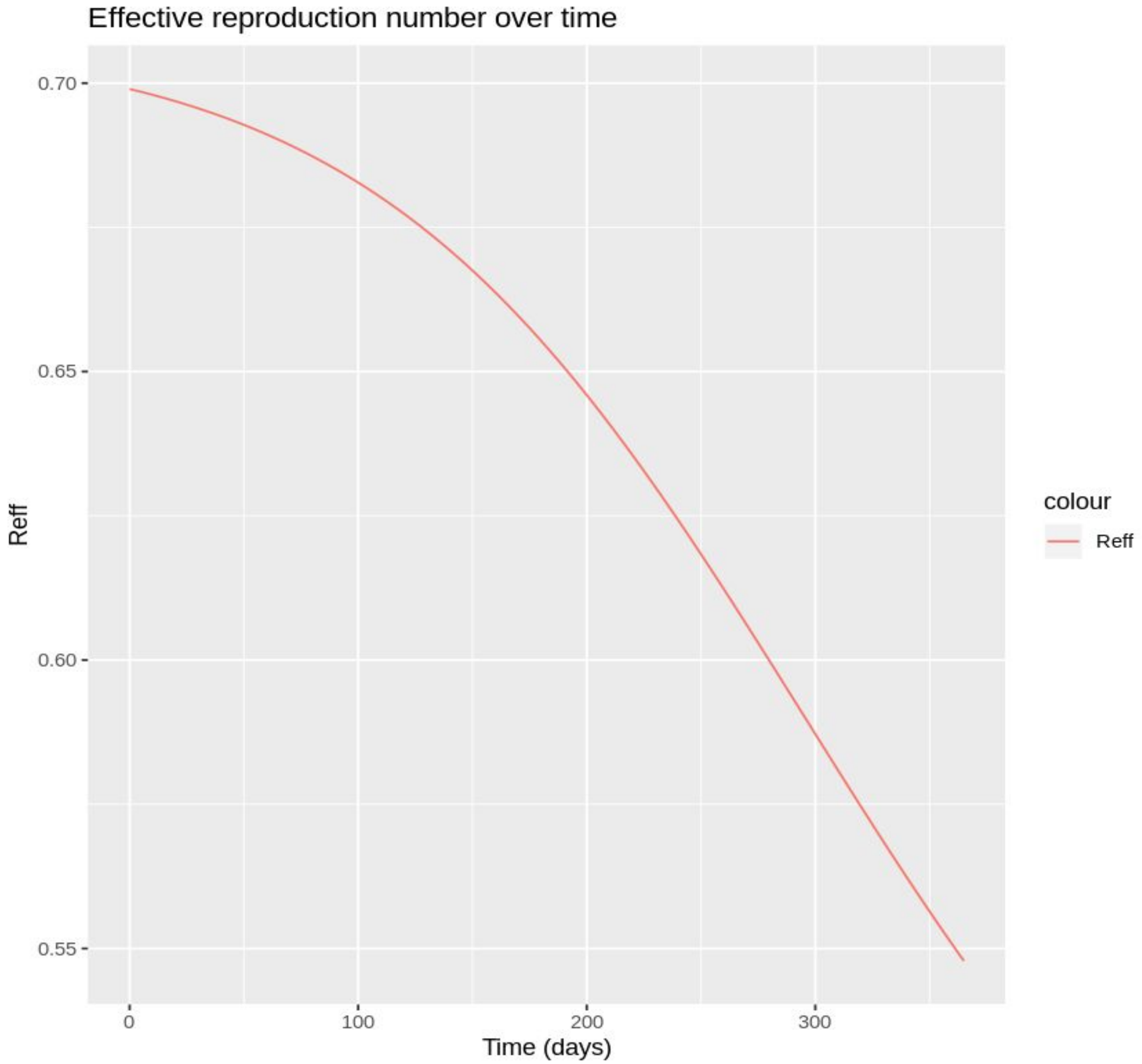
Ro - 0.90011



p = 0.4

Ro and Reff

R0 - 1.2073



WITHOUT USING DEVICE

Initial Values

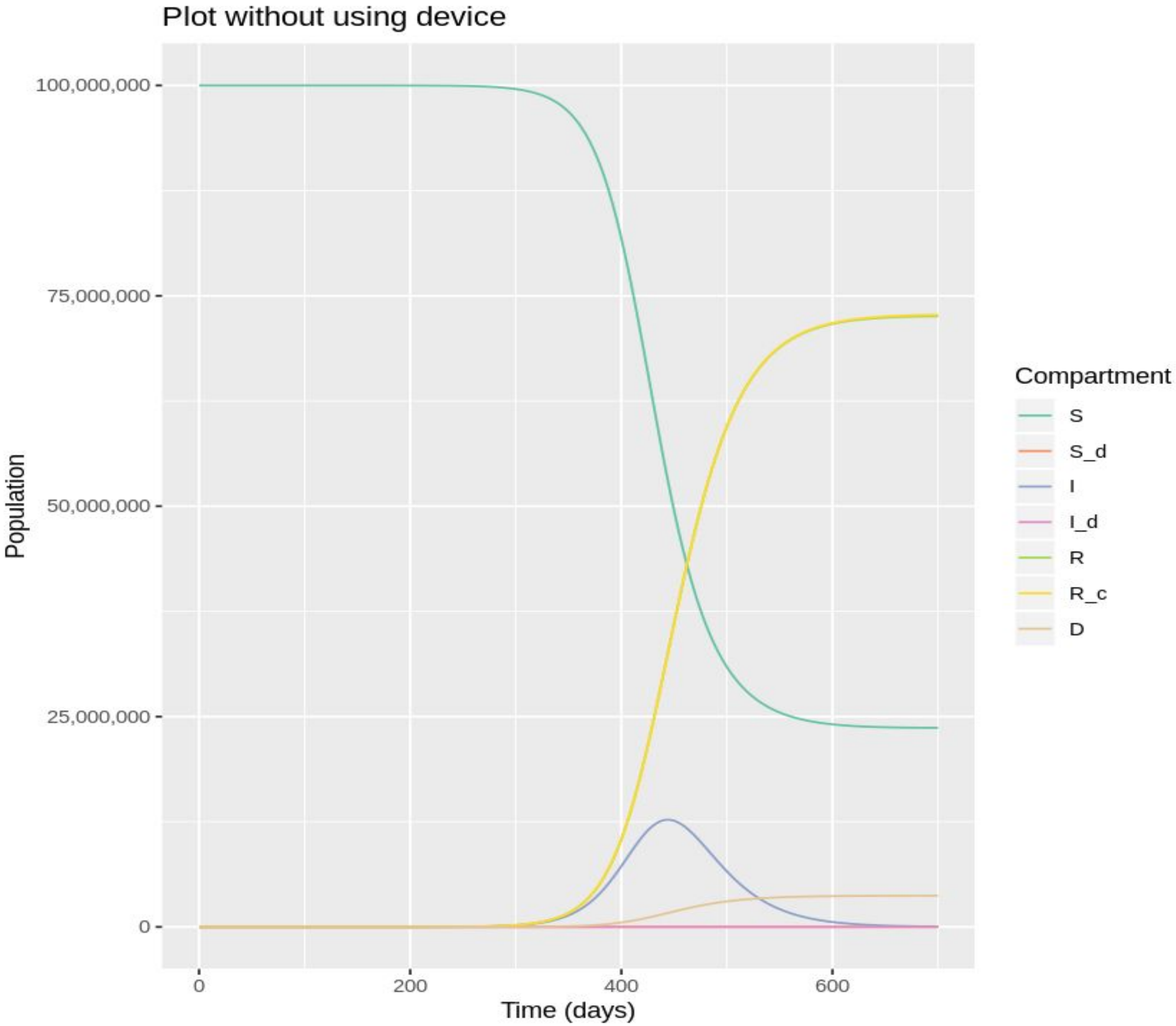
I = 3, #Infected no. of people not using device

I_d = 0, #Infected no. of people using device

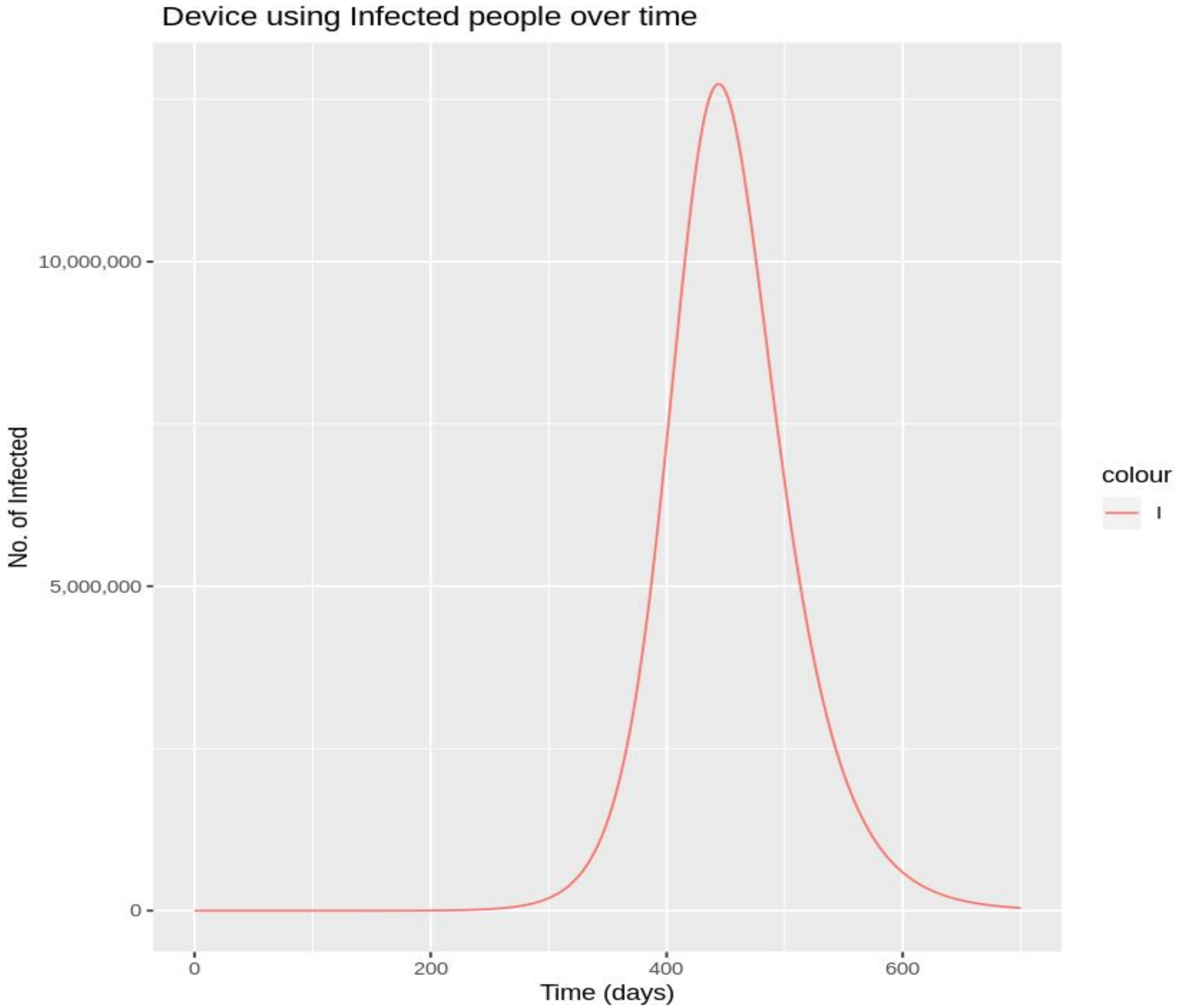
R = 0, #Recovered no. of people

D= 0 # Deaths

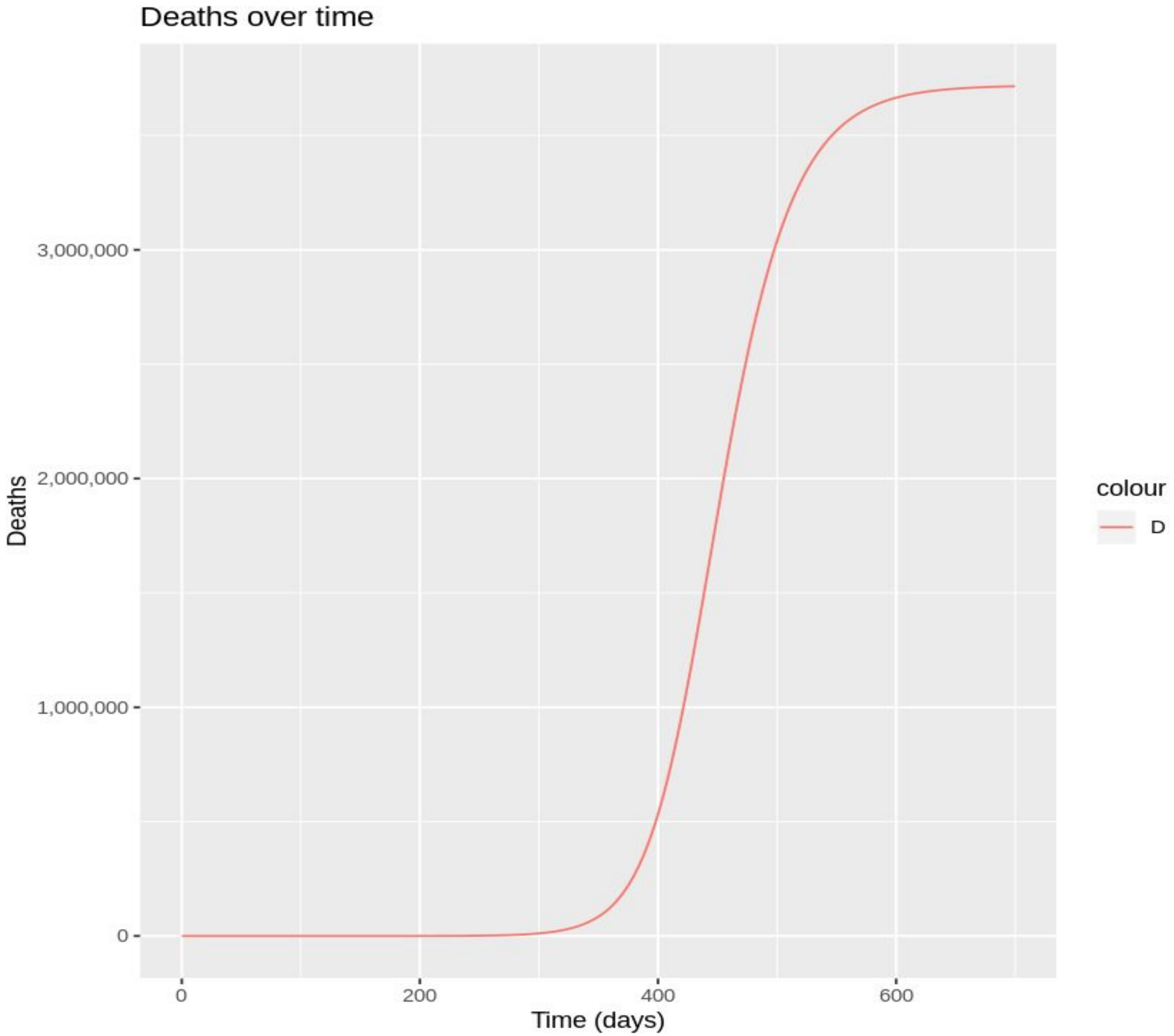
Plot of each compartment



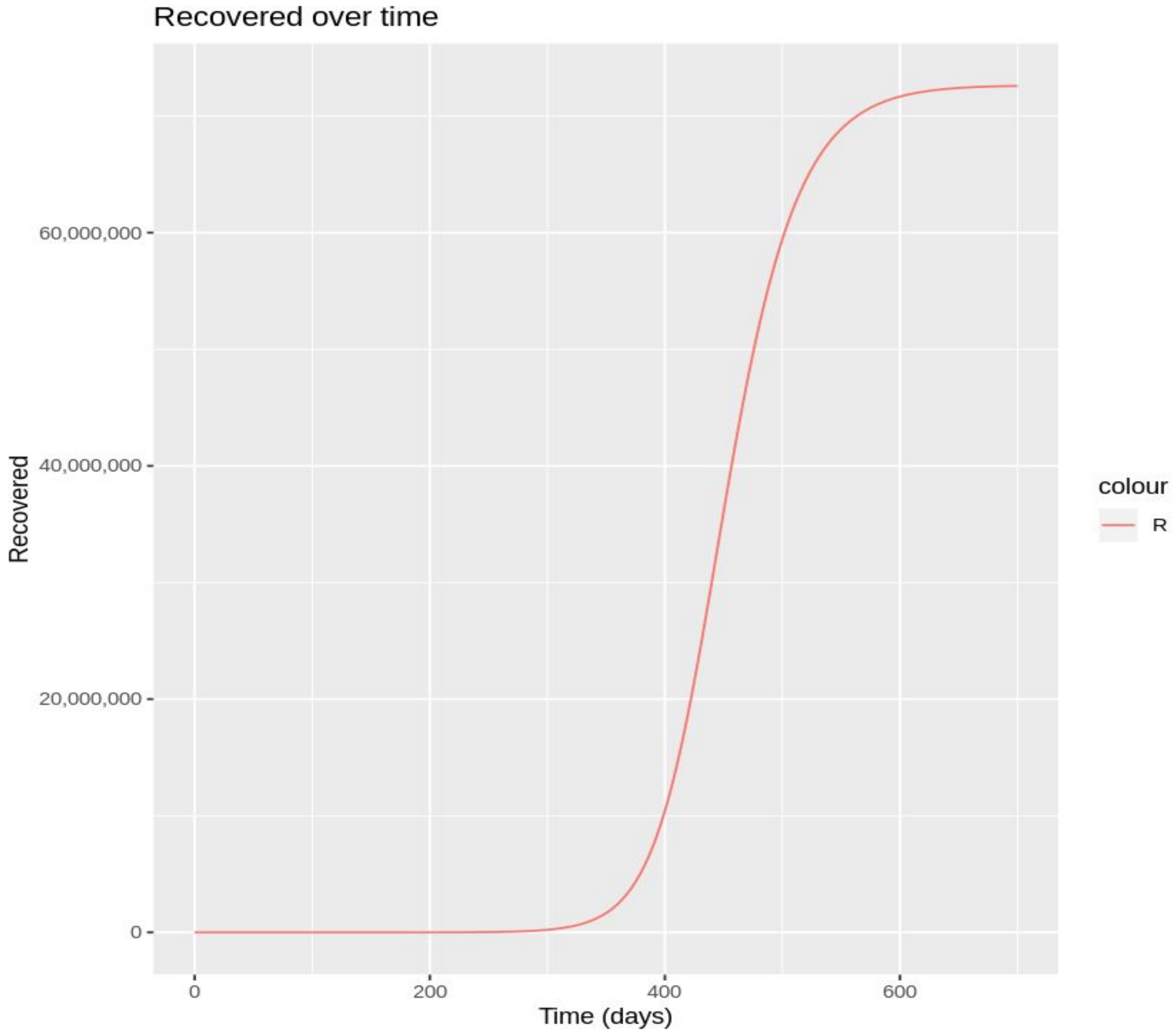
Total Active Cases



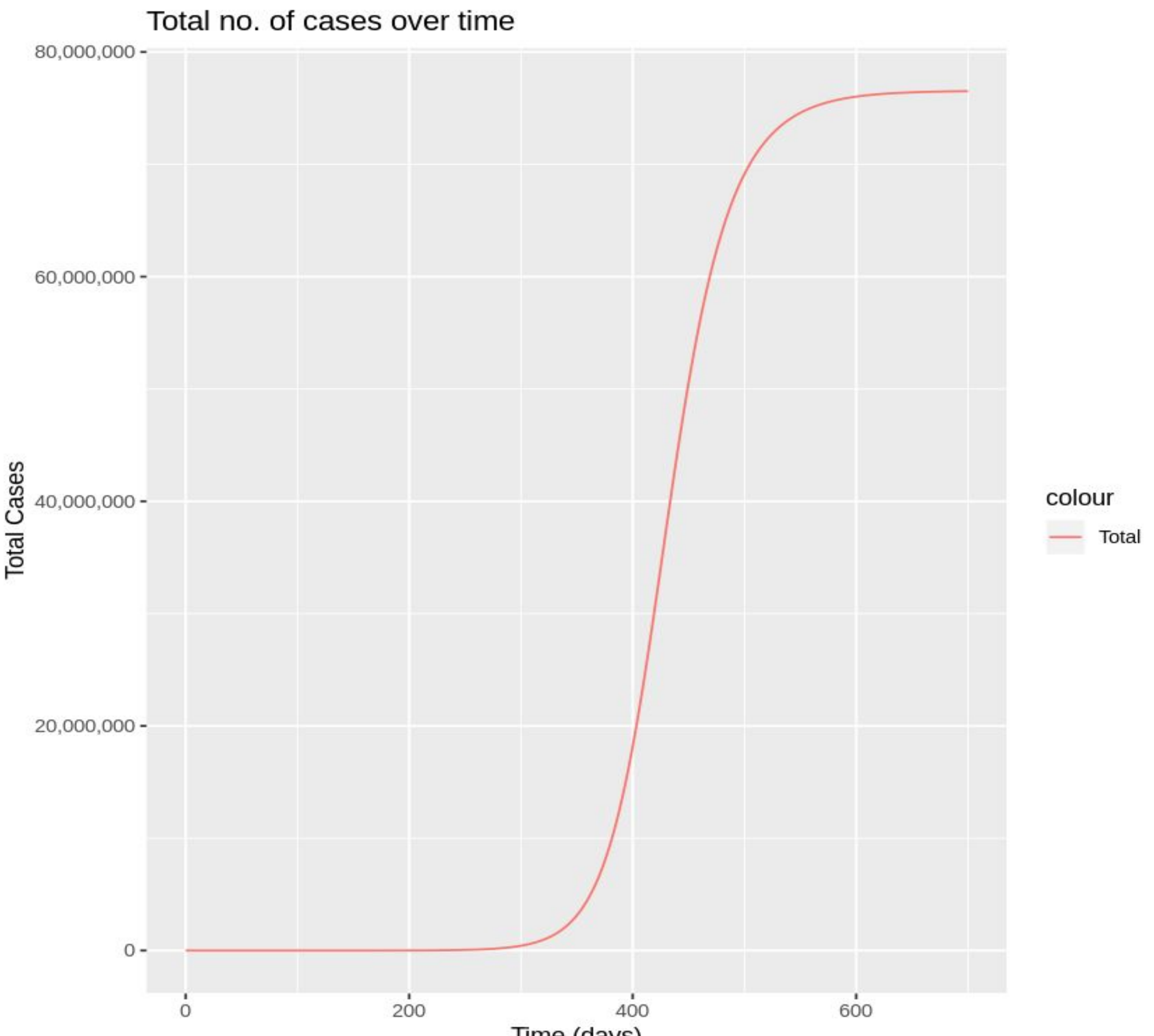
Total Deaths



Total Recovered



Total Infected Cases



Max value in each Compartment

Total = 7,65,12,063.35

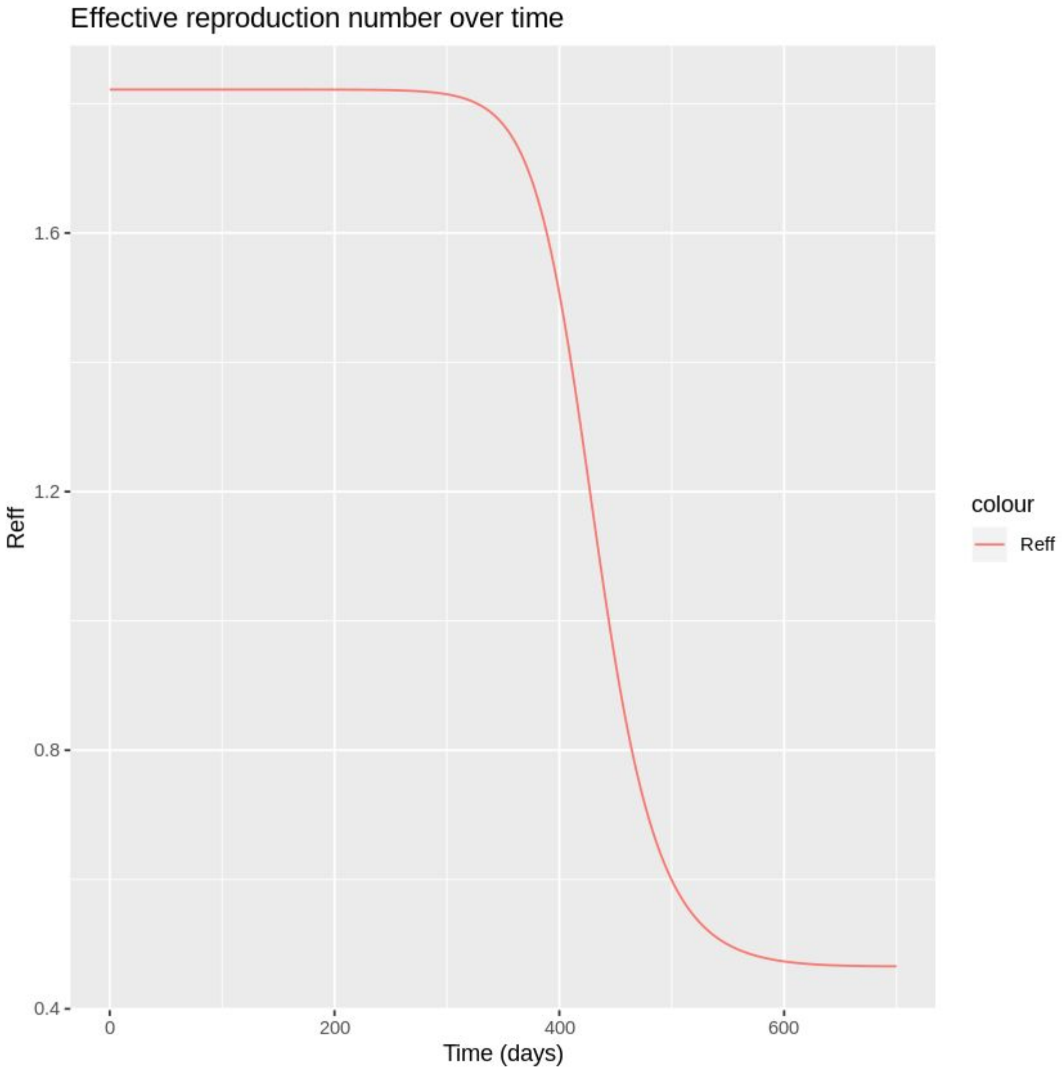
I = 1,27,38,369.4

D = 37,15,116.07

R= 7,27,54,356.5

Ro and Reff

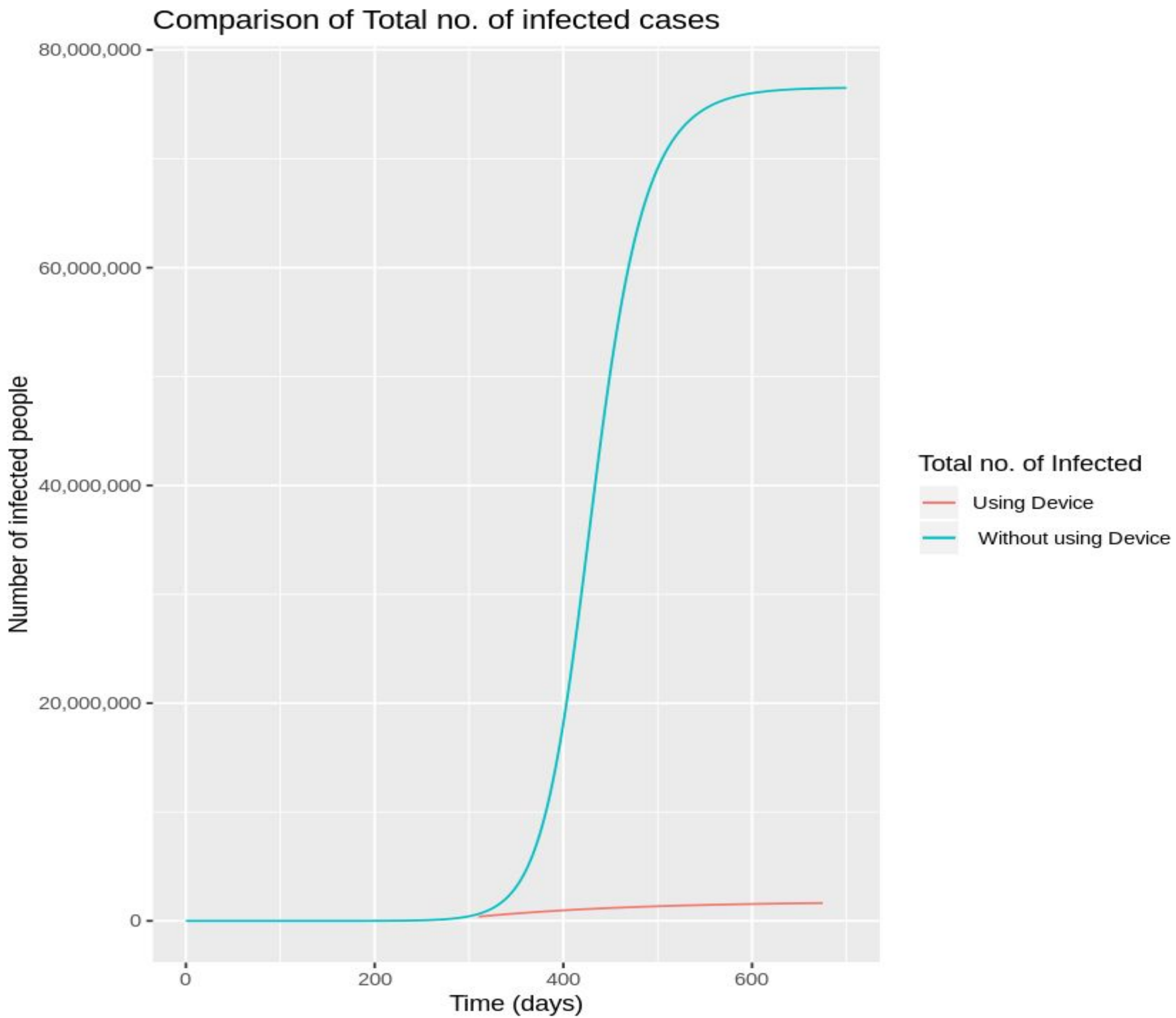
Ro = 1.8218



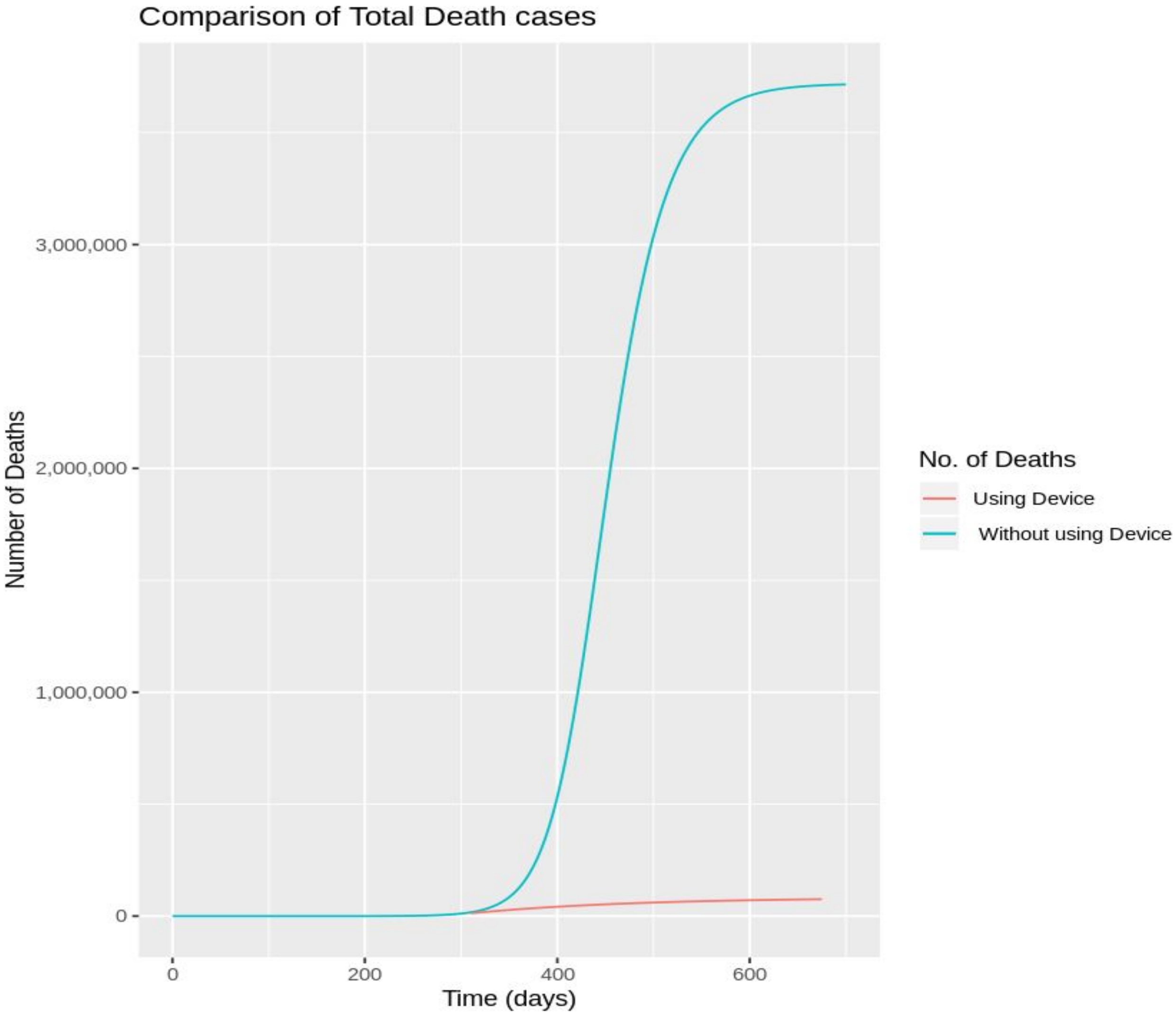
Comparison of values in each compartment with using Device and without using Device

Total Cases

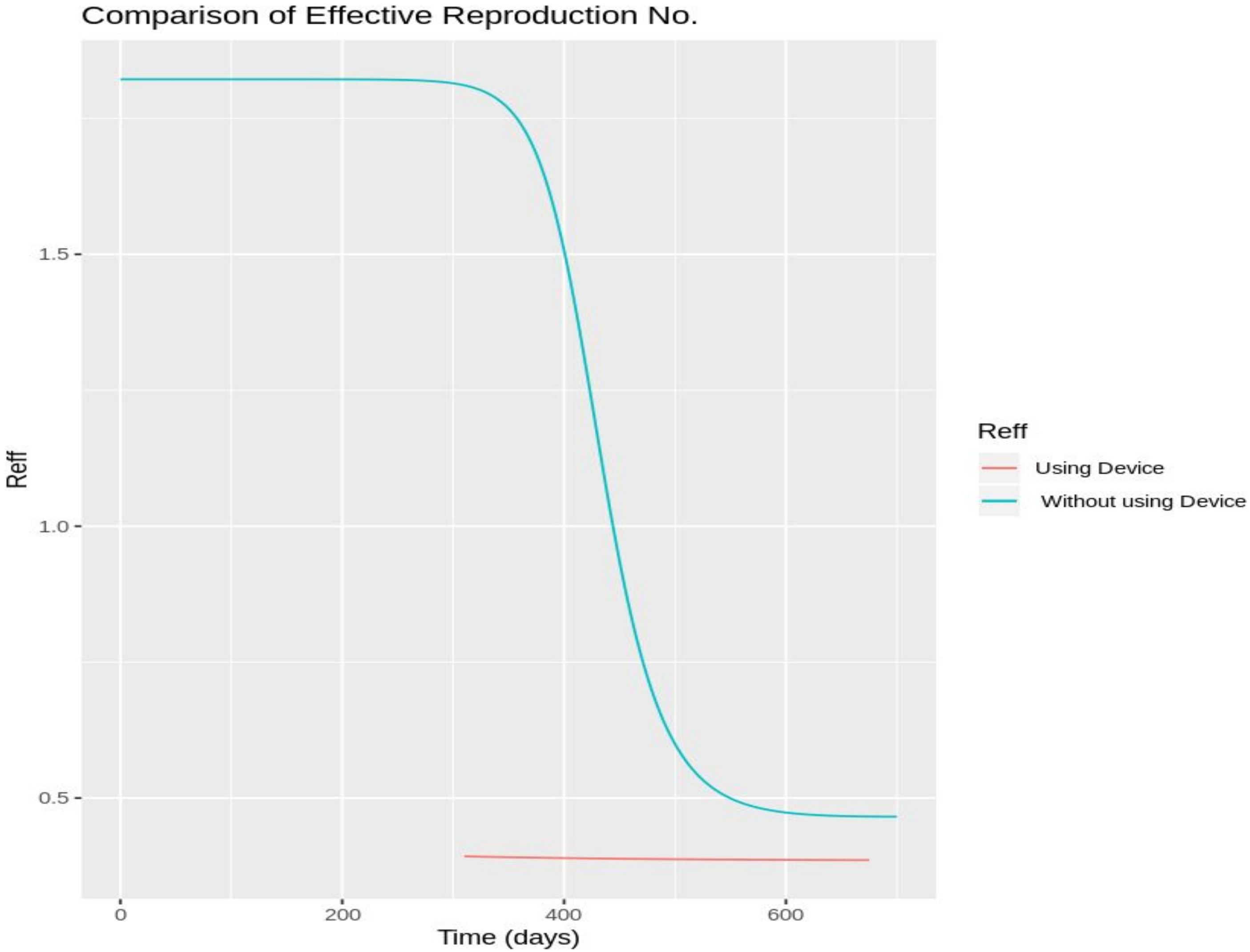
$p = 0.6$



Total Deaths



Reff



Comparison of Effective Reproduction No.
Reff
1.5
1.0
0.5
0
200
400
600
Time (days)
Reff
Using Device
Without using Device

COMPARISON WITH REAL DATA

Comapring with Data of India till 20th June’2020.

Parameters Equations

dD/dt = mu*I ==> mu = (dD/dt) * (1/I)

dR/dt = gamma*I ==> gamma = (dR/dt) * (1/I)

dI/dt = beta*S - gamma*I - mu*I ==> beta= (dI/dt +gamma*I + mu*I)*(1/S)

Two different sets of parameters

Using data of India till
20th of June

beta = 0.09

gamma = .047

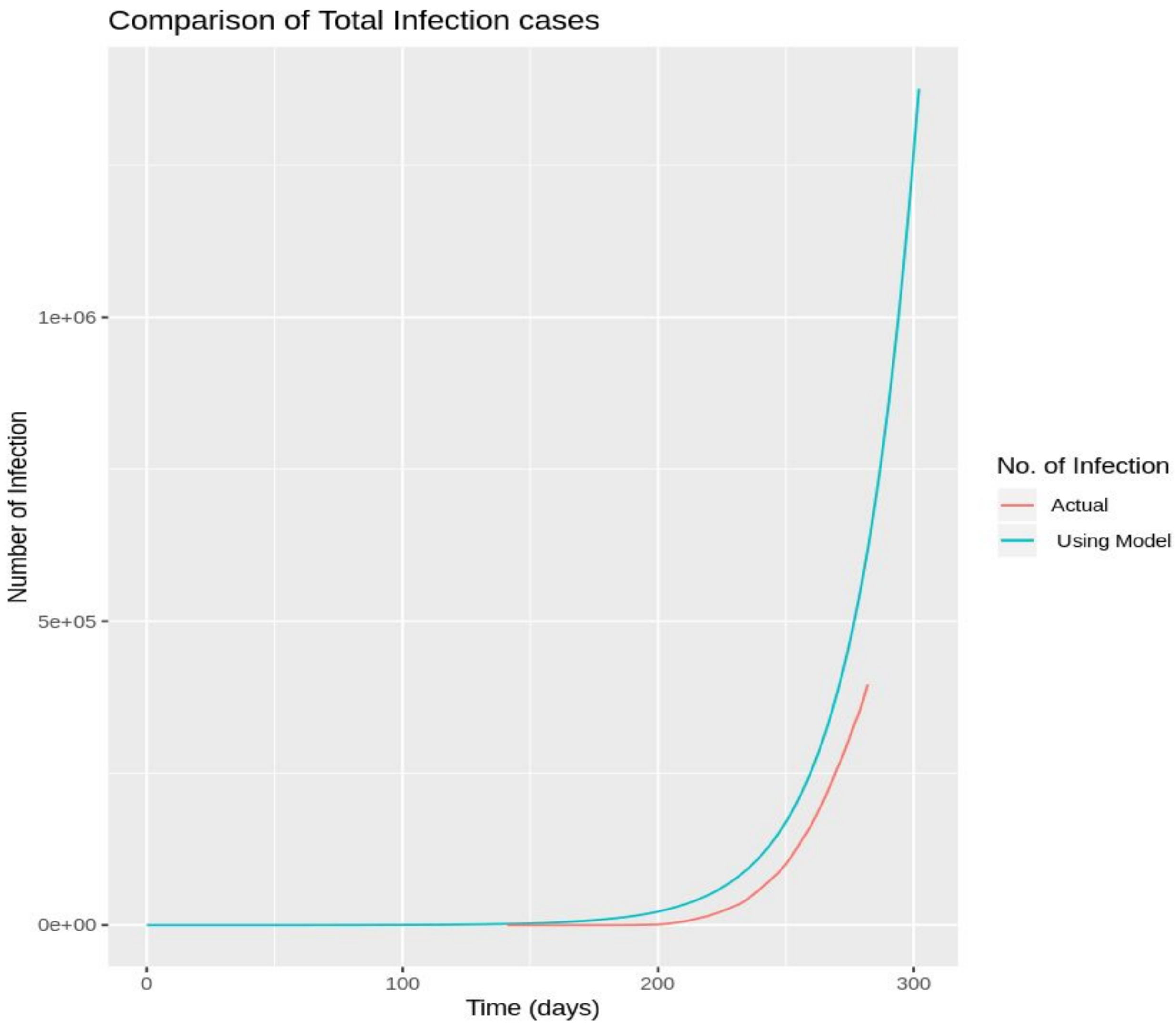
mu = 0.0024

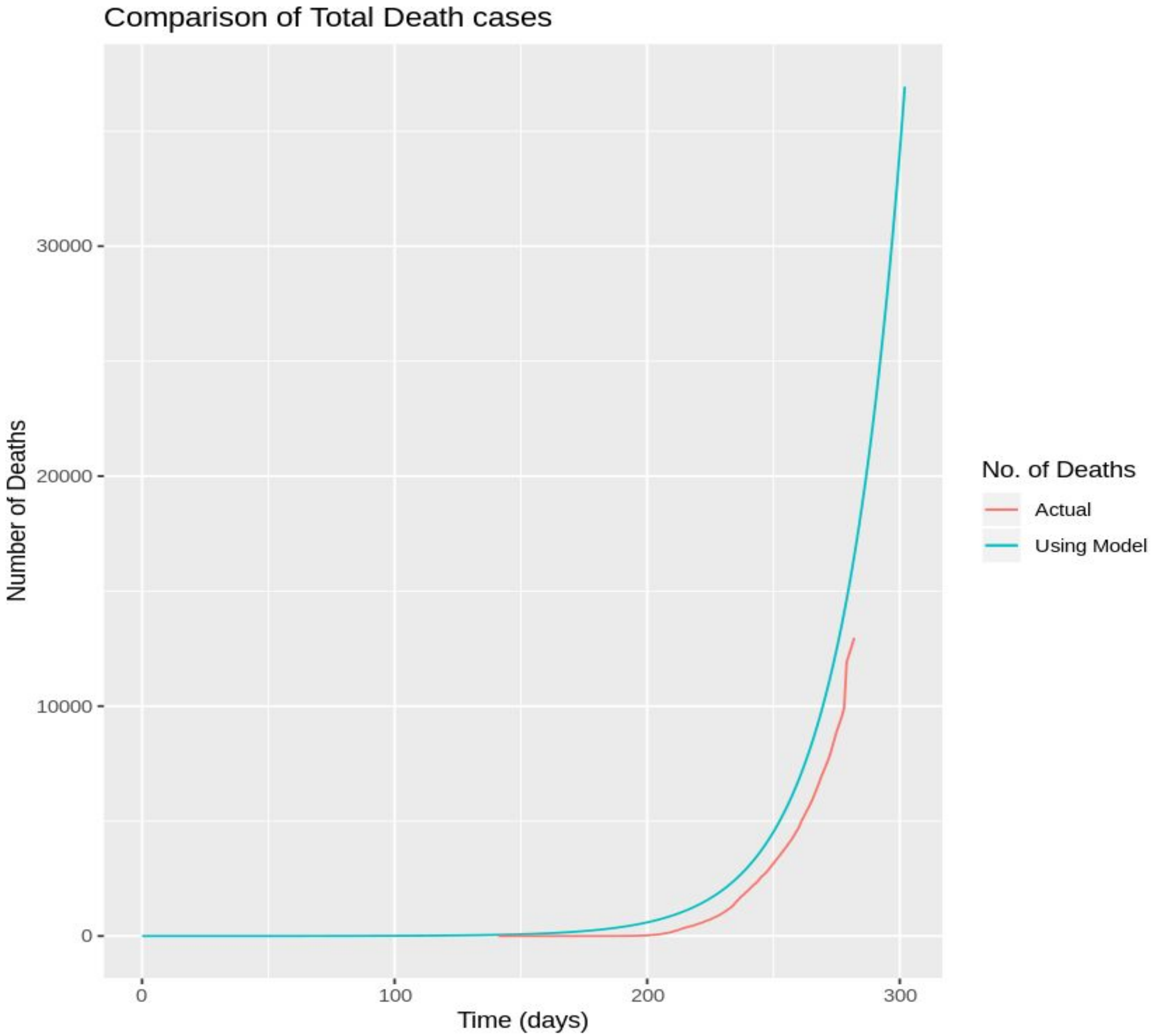
Using Least Square
Method

beta = 0.149

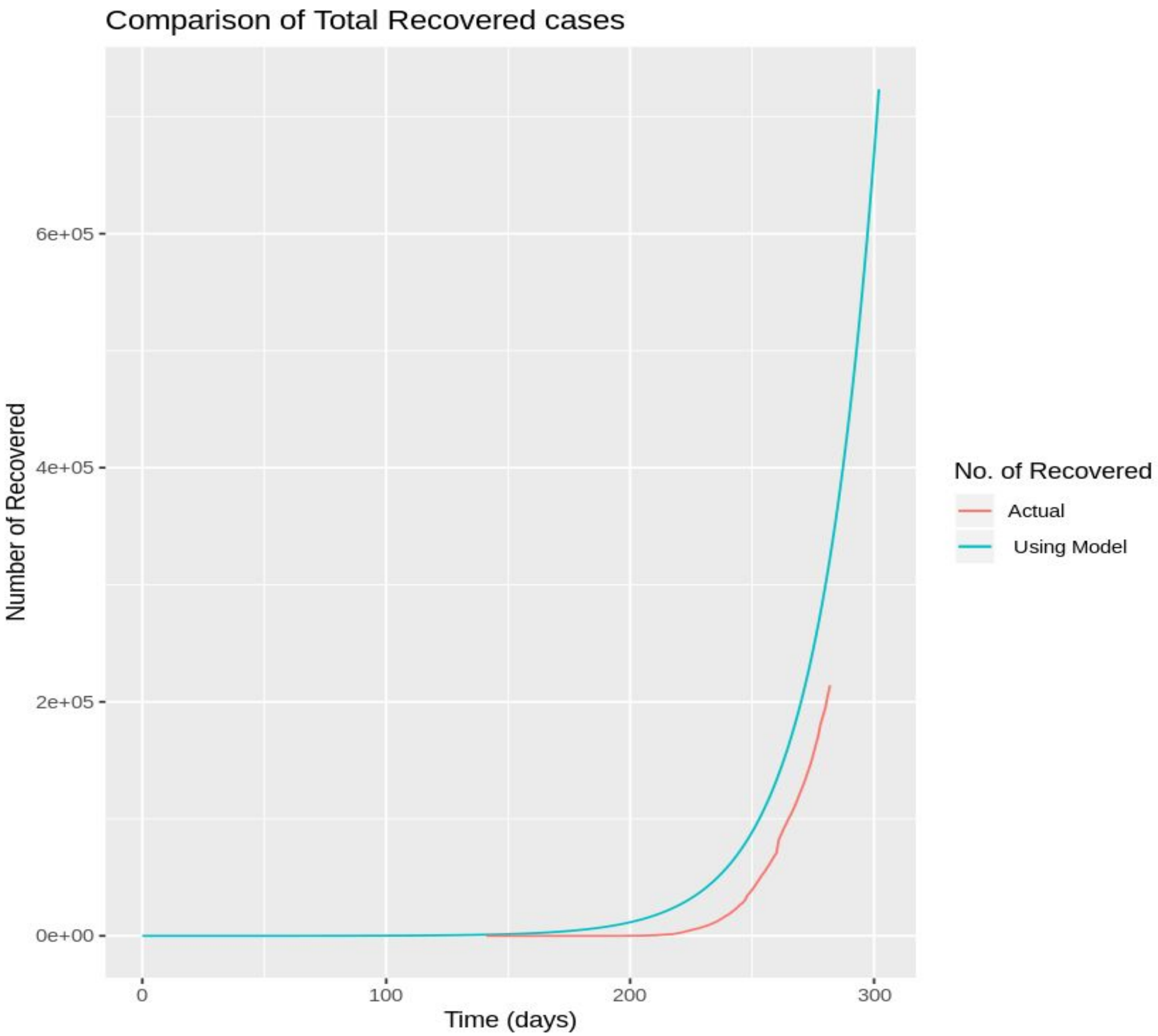
gamma = .061

mu = 0.003


Comparison of Total Infection cases
Number of Infection
1e+06
5e+05
0e+00
0
100
200
300
Time (days)
No. of Infection
Actual
Using Model

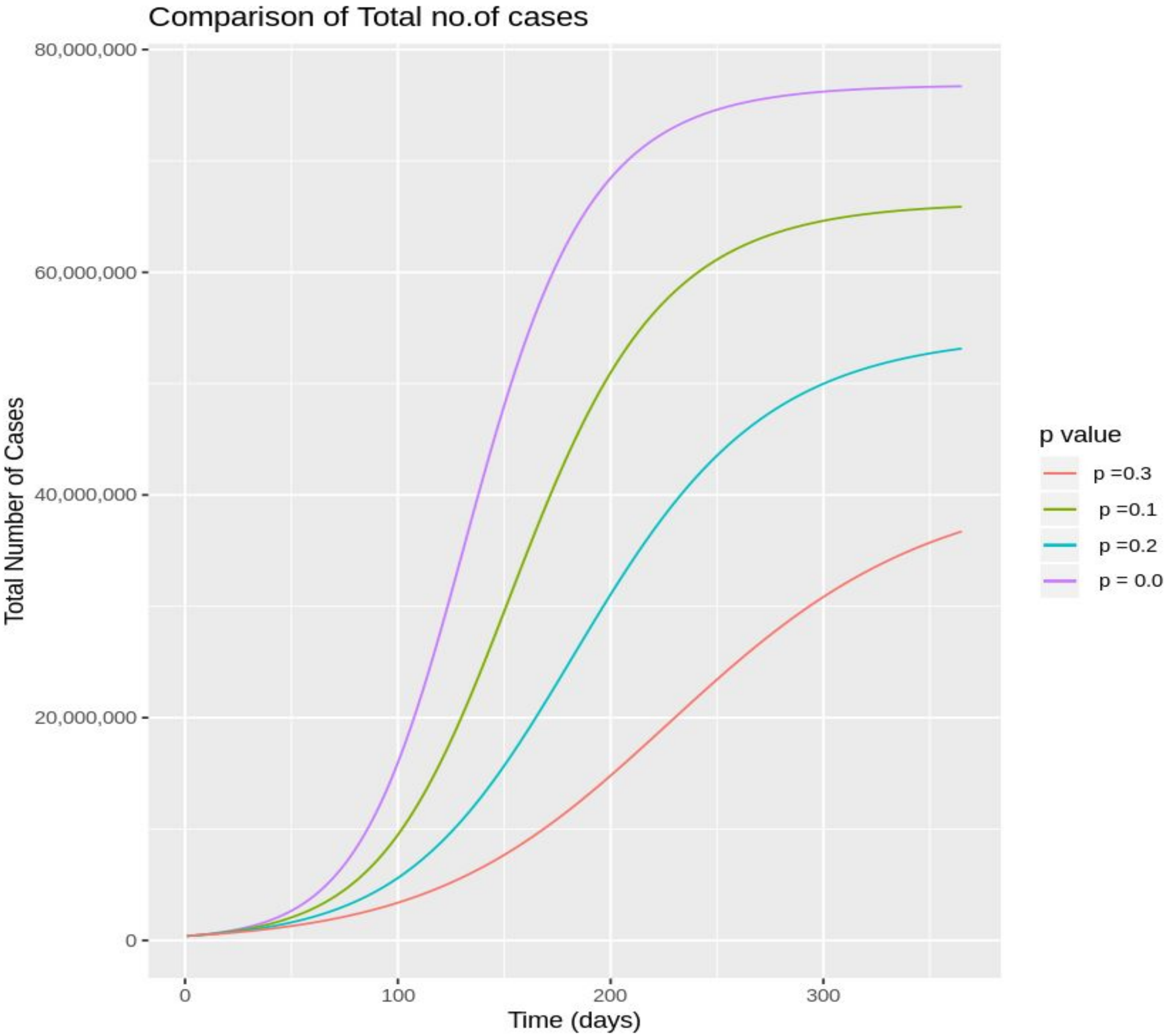


Comparison of Total Death cases
Number of Deaths
30000
20000
10000
0
0
100
200
300
Time (days)
No. of Deaths
Actual
Using Model

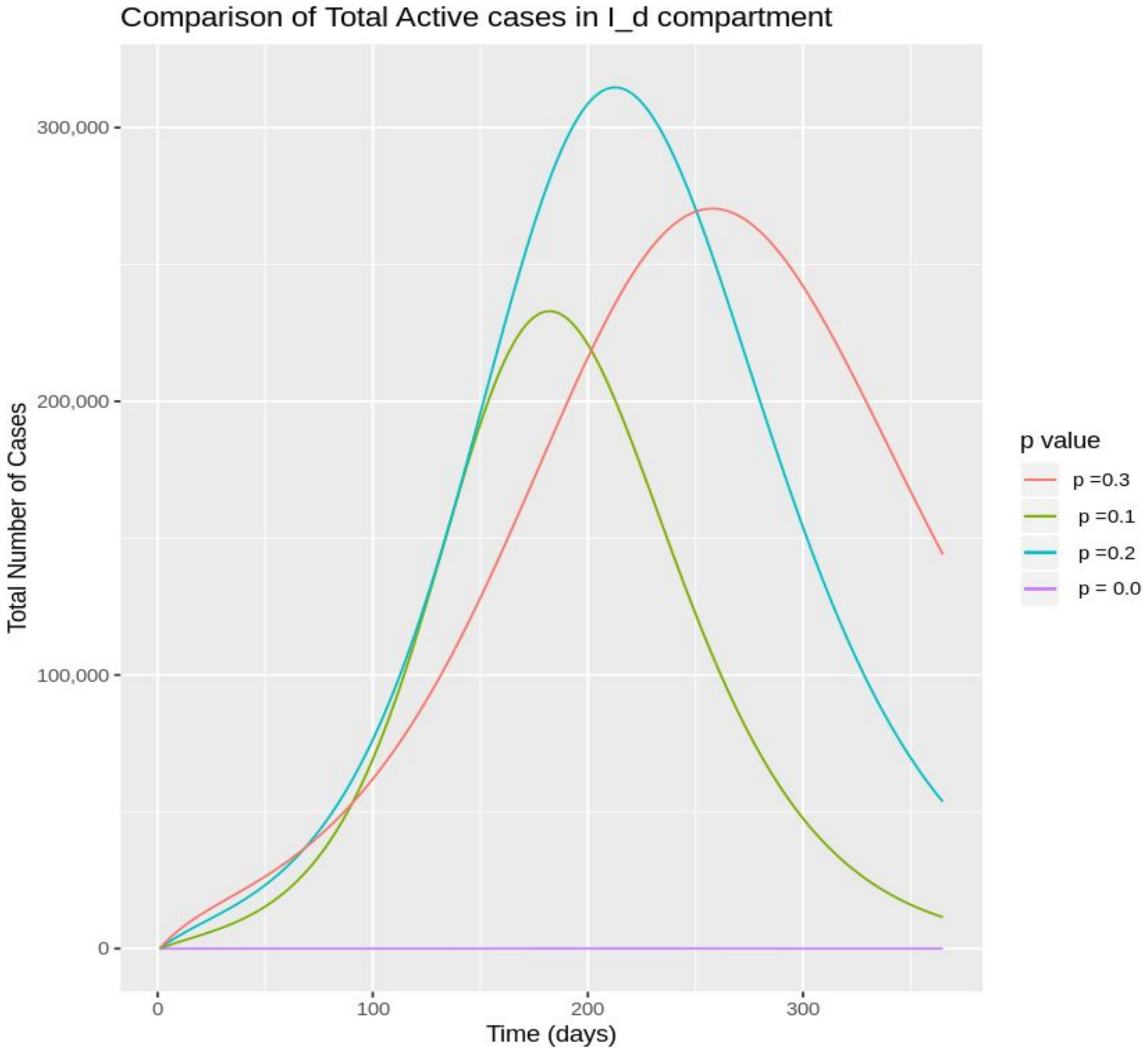

Comparison of Total Recovered cases
Number of Recovered
6e+05
4e+05
2e+05
0e+00
0
100
200
300
Time (days)
No. of Recovered
Actual
Using Model

Comparing using different p values

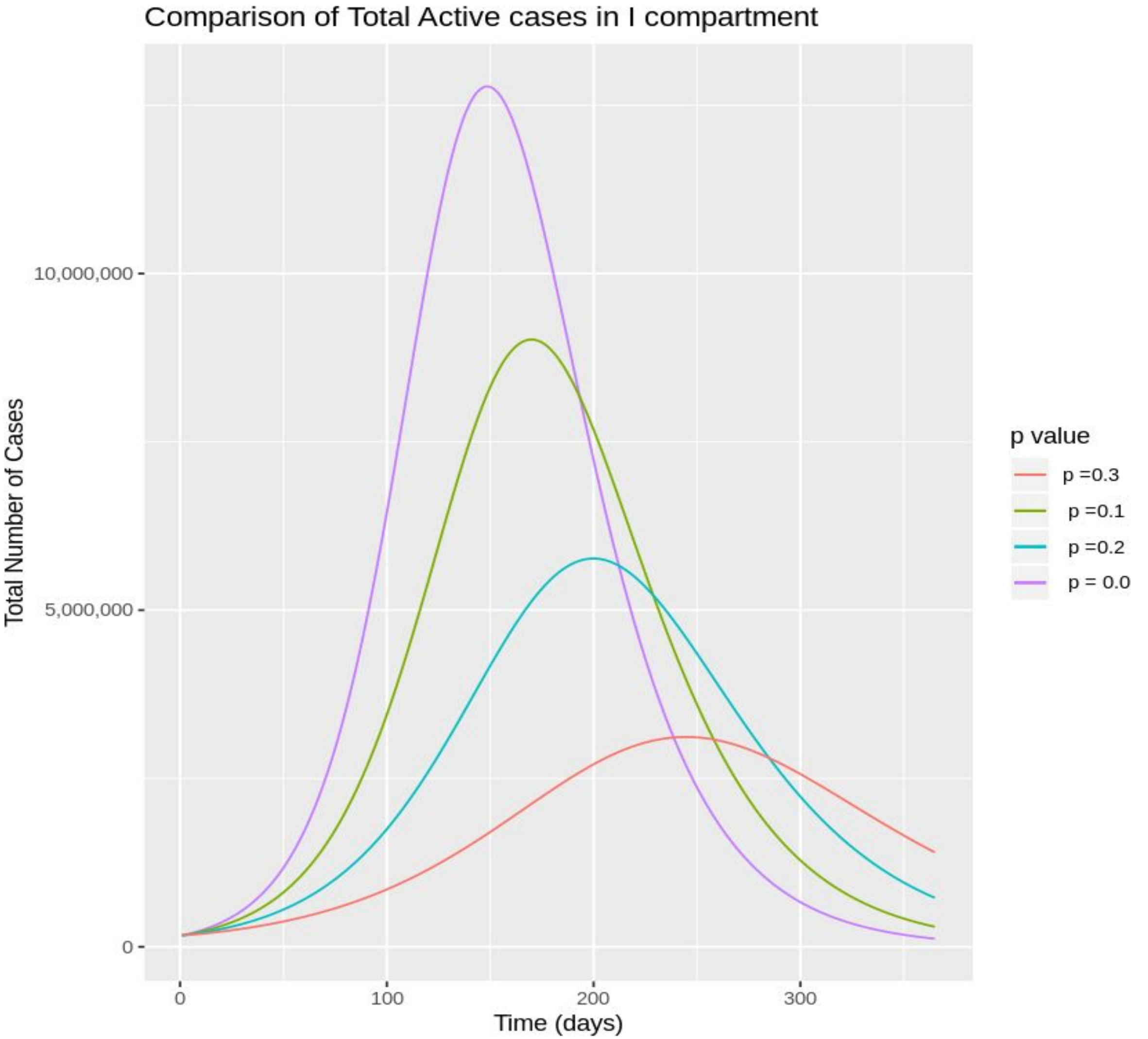
Total no.of cases



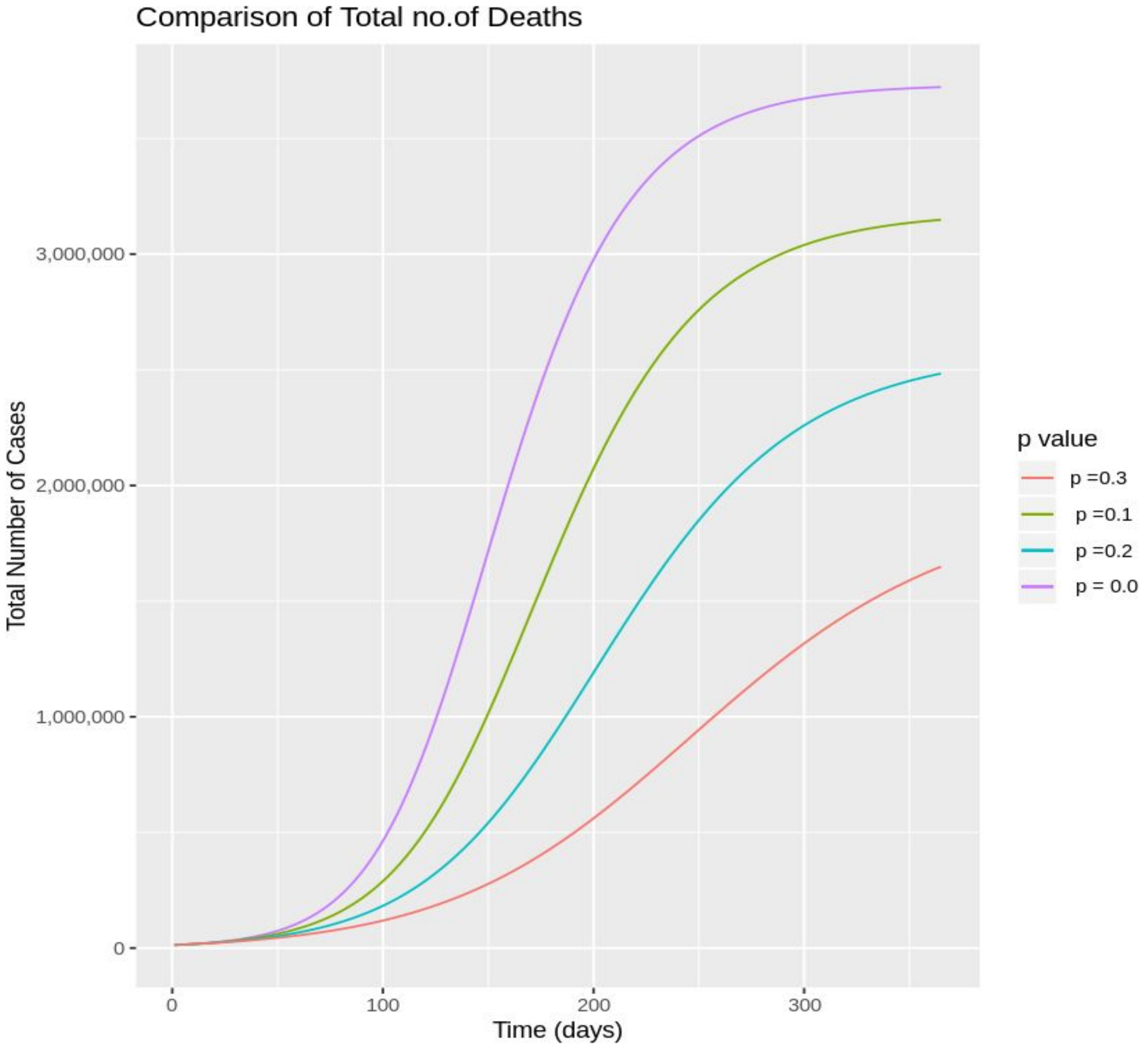
Total Active cases in I_d compartment



Total Active cases in I compartment



Total no.of Deaths



Reff values

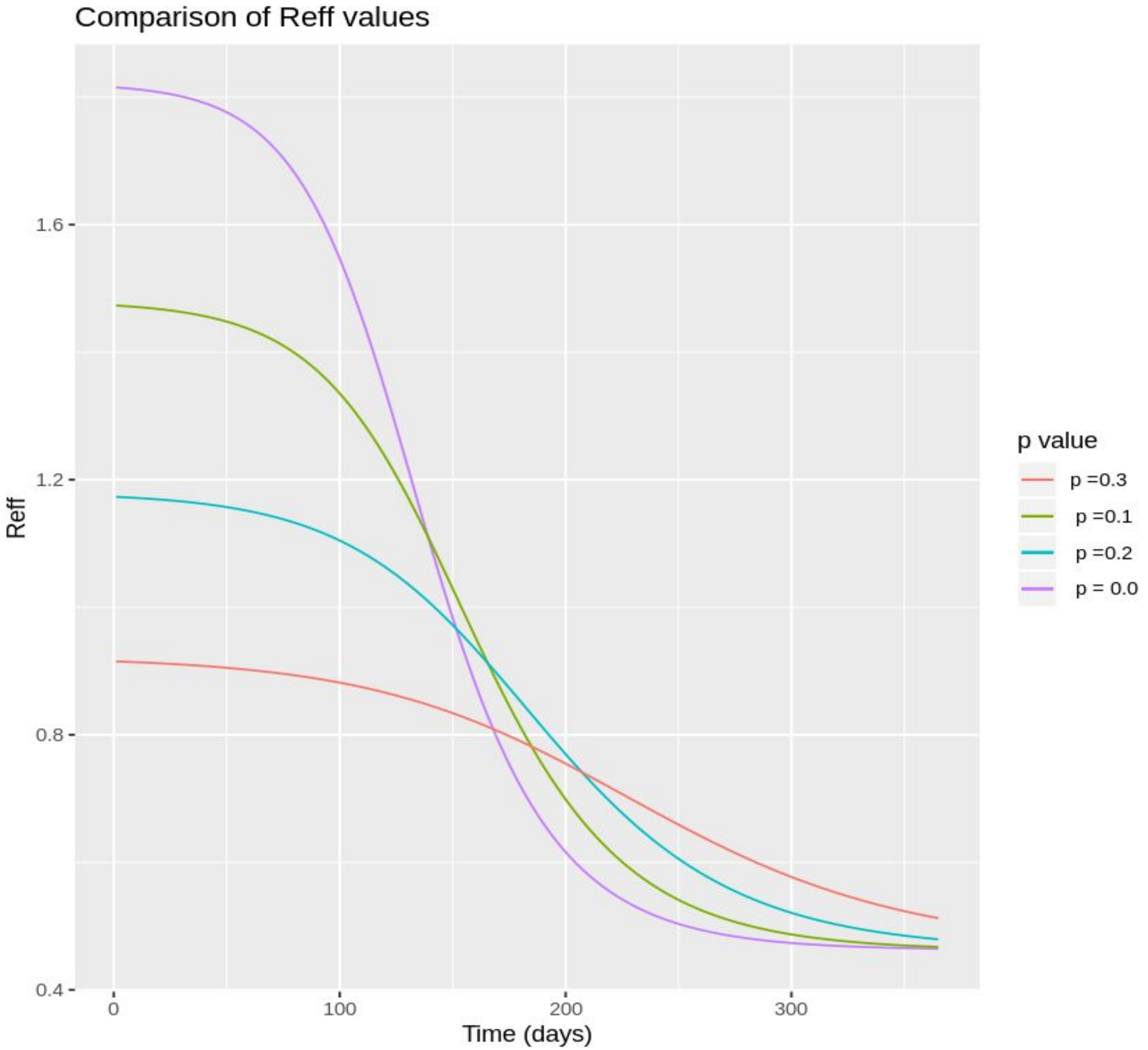
Ro Values

p = 0.0 Ro = 1.821

p = 0.1 Ro =1.668

p = 0.2 Ro = 1.514

p = 0.3 Ro = 1.360



References

https://www.coursera.org/learn/developing-the-sir-model

https://en.wikipedia.org/wiki/Basic_reproduction_number

https://idmod.org/docs/general/model-sir.html

https://web.stanford.edu/~jhj1/teachingdocs/Jones-on-R0.pdf

https://www.coursera.org/learn/interventions-and-calibration/home/welcome

https://www.kaggle.com/lisphilar/covid-19-data-with-sir-model#SIR-to-SIR-F

https://api.covid19india.org/